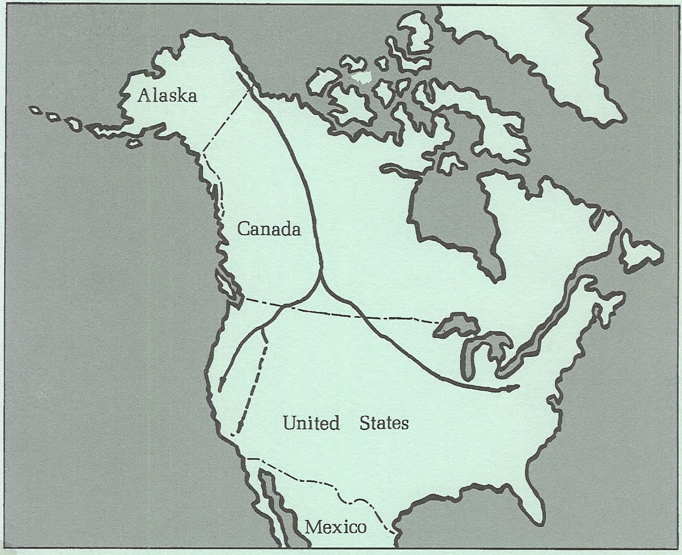
BLM LIBRARY
88045068

ALASKA NATURAL GAS TRANSPORTATION SYSTEM

Final Environmental Impact Statement

CANADA



MARCH 1976

U.S. DEPARTMENT OF THE INTERIOR

WASHINGTON, D.C. 20240

March 3, 1849

PROPERTY OF
Bureau of Land Management
DSC LIBRARY

BLM LIBRARY
RS 150A BLDG. 50
DENVER FEDERAL CENTER
P.O. BOX 25047
DENVER, CO 80225

ID88045068

TD 195 .P5 L362
1976h

~~ALAS~~
~~53~~
~~FES~~
~~V.4~~

ALASKA NATURAL GAS TRANSPORTATION SYSTEM

Final Environmental Impact Statement

March 1976

This final Environmental Impact Statement has been prepared under the provisions of Section 102(2)(C) of the National Environmental Policy Act of 1969 (P.L. 91-190). Contact regarding the document should be addressed to:

EIS Task Force
Alaska Natural Gas Transportation System
Bureau of Land Management (302)
U.S. Department of the Interior
Washington, D.C. 20240

W. W. Lyons

William W. Lyons
Deputy Under Secretary
Department of the Interior

Executive Director
EIS Task Force
Alaska Natural Gas
Transportation System

PROPERTY OF
Bureau of Land Management
DSC LIBRARY

BLM LIBRARY
RS 150A BLDG. 50
DENVER FEDERAL CENTER
P.O. BOX 25047
DENVER, CO 80225

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price $26 per 2 part set; sold in sets only
Stock Number 024-011-00067-4

SUMMARY

( ) Draft (x) Final Environmental Statement
United States Department of the Interior, Alaska Natural Gas Transportation System EIS Task Force

1. Type of action: (x) Administrative ( ) Legislative

2. Brief description of action: Action pending is granting rights-of-way permits for crossing Federal lands. A 5,580-mile buried pipeline has been proposed to transport natural gas from Prudhoe Bay (Alaska) to markets in the lower United States. The pipeline, as proposed, would cross all, or portions of, Alaska; Yukon Territory, Northwest Territories, British Columbia, Alberta, and Saskatchewan (Canada); and Idaho, Washington, Oregon, California, Montana, North Dakota, South Dakota, Minnesota, Iowa, Illinois, Indiana, Ohio, West Virginia, and Pennsylvania. As proposed, all activities necessary for pipeline construction and operation will be phased over a seven-year period. Of all lands traversed by the proposal, 406 miles will involve lands under the jurisdiction of five Federal agencies, all of whom have permitting authority. Other permits or licenses also must be issued before construction may begin or the project becomes operational.

3. Environmental impact and adverse environmental effects: Because of the linear nature of the proposal, a wide spectrum of environmental impacts will occur if the pipeline is built. Impacts, which are detailed in the Overview and geographically-oriented volumes, will occur on climate, topography, geology, soils, water resources, vegetation, fish and wildlife, social and economic environments, land use and productivity, cultural resources, recreation and esthetics, and air quality (including noise). All impacts will not be adverse.

4. Alternatives considered: Alternatives covered include the courses of action open to the Secretary of the Interior to approve, deny, postpone, or accept and delay or deny part of the proposal; effects of gas deregulation and conservation; other natural gas sources; alternative energy sources and modes of transportation; and one major alternative transportation system involving an all-Alaska gas pipeline, liquefaction plants, and LNG tanker transport to the conterminous United States.

5. Comments have been received from the following: Comments were received from 23 Federal agencies, 35 State and local governments, Canada, 17 companies representing industry, 16 private organizations, 100 individual citizens, and three members of Congress. Comments from Federal agencies, State and local governments, Canada, private organizations, and members of Congress are reproduced in the Consultation and Coordination volume. Other comments will be reproduced and filed as a supplement to this statement at selected repository sites.

6. Date made available to CEQ and the public:

Draft statement: July 28, 1975
Final statement: MAR 1976

Note for Readers

This environmental impact statement was prepared in response to applications made to the Secretary of the Interior for permits to cross Federal lands with a natural gas pipeline. It identifies and evaluates environmental impacts that could be expected from construction and operation of the "Alaska Natural Gas Transportation System" as proposed by the consortium of companies listed in the Consultation and Coordination volume. It was prepared by an interdisciplinary team, most of whom are employees of the United States Department of the Interior.

Detailed construction designs and detailed plans for site restoration and system operation are not complete at this (proposal) stage of the project. For this reason, some of the impacts and mitigating measures are expressed in ranges of magnitude or qualified to reflect alternative situations.

The Secretary of the Interior considers a number of factors in reaching his decision regarding issuance or denial of right-of-way permits. The environmental impact analysis presented in this statement is an important but not necessarily the deciding factor. Alternative gas transportation systems proposals, United States-Canada diplomatic relations, national economic and risk analyses, national defense implications, energy efficiency analyses, and other factors must also be considered.

This statement is presented in nine volumes as follows:

Overview Volume
Alaska Volume
Canada Volume
San Francisco Volume
Los Angeles Volume
North Border Volume
Alternatives Volume
Consultation and Coordination Volume
Glossary Volume

Alaska, Canada, San Francisco, Los Angeles and North Border Volumes are geographically oriented. The Overview Volume, Alternatives Volume, and Consultation and Coordination Volume are not geographically oriented in their coverage.

The following subject groupings are covered sequentially in each of the geographically oriented volumes and Overview:

1. Description of the proposal.
2. Description of the environment.
3. The environmental impact of the proposed action.
4. Mitigating measures proposed and additional measures considered.
5. Adverse effects which cannot be avoided should the proposal be implemented.

6. The relationship between local short-term uses of (man's resources) and the maintenance and enhancement of long-term productivity.
7. Irreversible and irretrievable commitments of resources associated with the proposed action.
8. Alternatives to the proposed route.

The reader can review particular segments of the proposed project selectively. For example, a reader interested only in impacts on North Dakota, could use the Overview Volume for the system "big picture," and the North Border Volume for coverage of his particular State. Similarly, a person interested primarily in ways of transporting natural gas could refer to the Alternatives Volume and satisfy his needs.

Following is a brief description of the coverage of each part:

> Overview Volume - The Overview covers the Arctic Gas System proposal in its entirety. It will be most useful to those readers who want a system view and a broad concept of anticipated environmental impacts of the entire pipeline project.
>
> Alaska Volume - This volume covers the 195-mile proposal of the Alaskan Gas Arctic Pipeline Company originating at Prudhoe Bay and terminating at the Alaska-Yukon Border and alternative routes.
>
> Canada Volume - This portion of the environmental impact statement analyzes the 2,435-mile pipeline proposal of Canadian Arctic Gas Pipeline, Ltd., beginning at the Yukon-Alaska Border and proceeding generally southward to Caroline Junction in Alberta where it forks, one leg entering Idaho, near Kingsgate, British Columbia, and the other entering Montana, near Monchy, Saskatchewan. Discussions of route alternatives are also presented.
>
> San Francisco Volume - This volume analyzes the 917-mile portion proposed by the Pacific Gas Transmission Company which passes through Idaho, Washington, and Oregon to Antioch, California. Discussions of route alternatives are presented.
>
> Los Angeles Volume - This volume relates to the 414-mile portion proposed by Interstate Transmission Associates (Arctic) extending from the point of United States entry in Idaho to Rye Valley, Oregon. It also involves modifications to existing compressor stations in Oregon, Idaho, and Colorado. Discussions of route alternatives are presented. This volume also contains a discussion of

the applicant's future proposal for an additional 760-mile pipeline passing through Idaho, Oregon, Nevada, and terminating at Cajon, California.

North Border Volume - This volume is an analysis of the 1,619-mile pipeline proposed by the Northern Border Pipeline Company. It covers the area from the United States-Canada border, crossing Montana, North and South Dakota, Minnesota, Iowa, Illinois, Indiana, Ohio, and West Virginia, to a termination near Delmont, Pennsylvania. Discussions of route alternatives are presented.

Alternatives Volume - This volume covers courses of action open to the Secretary of the Interior to approve, deny, postpone, or accept and delay or deny part of the proposal; effects of gas deregulation and conservation; other natural gas sources; alternative energy sources and modes of transportation; and one major alternative gas transportation system involving an all-Alaska gas pipeline, liquefication plants and tanker transport to the conterminous United States.

Consultation and Coordination - This volume describes and discusses the efforts made by the Department of the Interior to consult with and coordinate its work in the development of this statement. It includes the gathering of basic information for analysis, public meetings, public hearings, and efforts which have and will be made to assure that environmental impacts are adequately treated.

Glossary - This volume provides the reader with definitions of technical words or phrases used in the environmental impact statement.

TABLE OF CONTENTS

Page

Introduction-- 1
1 Description of the Proposed Action----------------------- 3
1.1 Arctic Gas Pipeline Project------------------------------ 3
1.1.2 Canadian Pipeline-- 3
1.1.2.1 Introduction--- 3
1.1.2.2 Location--- 5
1.1.2.3 Facilities--- 7

Pipeline-- 7
Compressor and Refrigeration Stations---------------- 10
Valves-- 18
Gas Measuring Stations------------------------------- 18
Communications-- 19
Roads--- 19
Airstrips and Helicopter Pads------------------------ 24
Wharves and Stockpiles------------------------------- 24
Borrow Pits--- 25
Construction Camps------------------------------------ 27
Cost of Facilities-------------------------------------- 30

1.1.2.4 Land Requirements--------------------------------------- 30
1.1.2.5 Schedule-- 30

Pipeline-- 30
Stations-- 32
Other Facilities--------------------------------------- 35

1.1.2.6 Construction Procedures--------------------------------- 35

Construction Zones------------------------------------ 35

Summer Construction Zone------------------------ 36
Conventional Winter Construction Zone----------- 36
Arctic Winter Construction Zone----------------- 36

Pipeline-- 36

Conventional Below-Grade Mode-------------------- 36
Special Construction Modes----------------------- 41

River Crossings---------------------------- 41
Road, Rail, and Foreign Pipeline Crossings-- 41
Pipeline at Stations, Valves, and Scraper Traps----------------------------------- 42

Compressor Stations---------------------------------- 42
Roads--- 43
Airstrips--- 43
Communications Sites---------------------------------- 43
Wharves--- 44
Human Resources--------------------------------------- 44

1.1.2.7 Operational, Maintenance, and Emergency Procedures--------- 44

Operations--- 44
Maintenance-- 47

Manpower--- 47
Equipment-- 47
Maintenance Strategy------------------------------- 52

Page

Preventive Maintenance---------------------- 52
Remedial Maintenance----------------------- 52

Contingency Planning---------------------------------- 54

1.1.2.8 Future Plans-- 56
1.1.2.9 Actions Involved-- 56

Federal-- 57

The National Energy Board------------------------ 57
The Department of Indian Affairs and Northern Development------------------------------------ 57
Consolidated Investigation and Decision----- 57
Hearings------------------------------------ 57

Provincial--- 58

Authorizations----------------------------------- 58

Application of Provincial Law--------------- 58
Pre-negotiation Information Needs----------- 58
Public Hearing Meetings--------------------- 59

References-- 59

2 Description Of The Existing Environment-------------------- 61
2.1 Arctic Gas Pipeline Project--------------------------- 61
2.1.2 Canadian Pipeline------------------------------------ 61
2.1.2.1 Climate-- 61

Temperature-- 61
Precipitation-------------------------------------- 61
Wind--- 62

2.1.2.2 Topography--- 62

Organization of Discussion---------------------- 66

Summary Description of Route------------------------ 66

Location--- 66
Drainage Basins---------------------------------- 66
Slopes--- 66
Elevations--------------------------------------- 66
Relief--- 68

Route Description------------------------------------- 68

Prudhoe Bay Supply Line-------------------------- 68
Richards Island Supply Line---------------------- 68
Main Line, Travaillant Lake Junction to Alberta Border-- 69
Main Line, Alberta Border to Caroline Junction--- 70
Monchy Delivery Line----------------------------- 71
Kingsgate Delivery Line-------------------------- 71

2.1.2.3 Geology-- 72

Page

Physiography-- 72

Description of Physiographic Regions------------ 75

Interior Plains Region---------------------- 75
Arctic Coastal Plains Region---------------- 75
Cordilleran Region-------------------------- 75

Description of the Proposed Route North of 60° North Latitude---------------------------------- 76

Prudhoe Bay Supply Line--------------------- 76
Richards Island Supply Line----------------- 77

Description of the Proposed Route South of 60° North Latitude---------------------------------- 80

Main Line, Alberta-N.W.T. Border to Caroline Junction------------------------- 80
Monchy Delivery Line------------------------- 80
Kingsgate Delivery Line--------------------- 80

Bedrock--- 85

North of 60° North Latitude--------------------- 90

Prudhoe Bay Supply Line--------------------- 90
Richards Island Supply Line----------------- 90
Main Line----------------------------------- 90

South of 60° North Latitude--------------------- 91

Main Line To Caroline Junction-------------- 91
Monchy Delivery Line------------------------ 91
Kingsgate Delivery Line--------------------- 91

Surficial Deposits---------------------------------- 91

North of 60° North Latitude--------------------- 91

Prudhoe Bay Supply Line--------------------- 94
Richards Island Supply Line----------------- 95
Parsons Lake Lateral Line------------------- 96
Main Line----------------------------------- 97

South of 60° North Latitude--------------------- 100

Main Line----------------------------------- 100
Monchy Delivery Line------------------------ 106
Kingsgate Delivery Line--------------------- 108

Mineral Resources----------------------------------- 111

Metallic and Nonmetallic Minerals--------------- 111
Oil and Gas------------------------------------- 111

Geologic Hazards------------------------------------ 116

Seismicity-------------------------------------- 116

Page
Erosion and Slope Stability-------------------- 117

General Drainage and Erosion--------------- 117
Slope Stability---------------------------- 118
River Crossing Characteristics------------- 124

Other Geologic Hazards------------------------- 124

Permafrost--- 125

General Description---------------------------- 125

Definition--------------------------------- 125
Distribution------------------------------- 125
Thickness---------------------------------- 126
Depth to Permafrost------------------------ 126
Temperature-------------------------------- 129
Ice Content-------------------------------- 129
Modifications of Permafrost---------------- 130

Description Alonα the Proposed Route------------ 130

North of 60° North Latitude---------------- 131
South of 60° North Latitude---------------- 132

2.1.2.4 Soils-- 133

Soils Along the Proposed Route--------------------- 138

Chernozemic Soils------------------------------ 138

Brown Chernozemic Soils-------------------- 138
Dark Brown Chernozemic Soils--------------- 138
Black Chernozemic Soils-------------------- 139

Solonetzic Soils------------------------------- 139

Brown Solonetz----------------------------- 139
Black Solonetz----------------------------- 139
Solod-------------------------------------- 139

Luvisolic Soils-------------------------------- 140

Gray Luvisols------------------------------ 140

Brunisolic Soils------------------------------- 140

Eutric Brunisols--------------------------- 140
Dystric Brunisols-------------------------- 141

Regosolic Soils-------------------------------- 141

Orthic Regosols---------------------------- 141
Cumulic Regosols--------------------------- 142
Cryic Regosols----------------------------- 142

Gleysolic Soils-------------------------------- 143

Humic Gleysols----------------------------- 143
Gleysols----------------------------------- 143

Page
Cryic Gleysols---------------------------- 143

Organic Soils----------------------------------- 143

Fibrisols and Mesisols--------------------- 143
Cryic Fibrisols---------------------------- 144

Miscellaneous Areas----------------------------- 144

2.1.2.5 Water Resources-- 144

Surface Water-- 144

Arctic Ocean Drainage Basins-------------------- 158
Mackenzie River System-------------------------- 166

Lower Mackenzie River Basin---------------- 166
Upper Mackenzie River Basin---------------- 173

Nelson River System----------------------------- 174
Mississippi-Missouri River System--------------- 176

Frenchman River Basin---------------------- 176

Columbia River System--------------------------- 176

Kootenay River Basin----------------------- 176

Ground Water--- 177

Ground Water in the Northern Region------------- 179
Ground Water in the Interior Plains Region------- 180
Ground Water in the Cordilleran Region---------- 182
Water Quality----------------------------------- 182

2.1.2.6 Vegetation--- 184

Major Plant Formations, Associations and Communities-- 185

Yukon and Northwest Territories----------------- 185

Tundra Formation--------------------------- 185
Forest-Tundra Formation-------------------- 191
Boreal Forest Formation-------------------- 191

Alberta, Saskatchewan and British Columbia------- 196

Boreal Forest Formation-------------------- 196
Parkland Formation------------------------- 199
Grassland Formation------------------------ 200
Subalpine Forest Formation----------------- 200
Interior Wet Belt Forest Formation--------- 200

Human Influences on Existing Vegetation-------------- 201

Page
General Nature of Influence---------------------- 201

Prudhoe Bay Supply Line--------------------- 202
Richards Island Supply Line----------------- 202
Mainline--Travaillant Lake to N.W.T.-Alberta Border--------------------------- 203
N.W.T.-Alberta Border to Caroline Junction-- 203
Kingsgate Delivery Line--------------------- 204
Monchy Delivery Line------------------------ 204

Unique, Sensitive, and/or Threatened Ecosystems or Communities-- 204
Threatened Species------------------------------------ 205

2.1.2.7 Wildlife--- 205

Fishery Resources------------------------------------- 205

Beaufort Sea Drainage--------------------------- 205
Mackenzie River Drainage------------------------ 210
Saskatchewan and Mississippi River Drainages----- 216
Columbia River Drainages------------------------ 216

Mammals--- 222

North of 60° North Latitude--------------------- 222
South of 60° South Latitude--------------------- 227

Birds--- 228

Prudhoe Bay Supply Line------------------------- 228
Richards Island Supply Line--------------------- 240
Northern Mackenzie Segment of the Main Line------ 240
Southern Mackenzie Segment of the Main Line------ 240
Alberta Segment of the Main Line---------------- 241
Monchy Delivery Line---------------------------- 241
Kingsgate Delivery Line------------------------- 242

2.1.2.8 Ecological Considerations------------------------------ 242

Ecosystem Productivity-------------------------------- 244
Ecosystem Interrelationships-------------------------- 245

2.1.2.9 Economic Factors--------------------------------------- 246

History of Economic Development---------------------- 246
Principal Economic Activities------------------------- 249

Economic Products------------------------------- 254
Economic Markets-------------------------------- 254

Employment and Income--------------------------------- 254

Principal Employers and Workforce Statistics----- 255
Income Characteristics-------------------------- 257

Local Tax Structure and Base Characteristics---------- 260

Principal Sources of Tax Income----------------- 260
Distribution of Revenues for Public Services----- 262

Economic Trends Without the Proposed Project---------- 262

Page

2.1.2.10 Sociological Factors-- 266

Population-- 266

Northwest Territories-------------------------- 266

History of Area Population Growth----------- 266
Current Population------------------------- 266
Ethnic Breakdown--------------------------- 266

Provinces-- 269

Community Structure-------------------------------- 273

Local Government------------------------------- 273

Northwest Territories---------------------- 273
Alberta------------------------------------ 276

Housing Characteristics------------------------ 276

N.W.T.------------------------------------- 276
Alberta------------------------------------ 277

Education, Health, and Waste Disposal Services--- 279

Education---------------------------------- 279
Health------------------------------------- 280
Other Services----------------------------- 280

Unique Features of Northwest Territories Study Area--- 281
Area Trends-- 282

Population--------------------------------------- 282
Community Structure------------------------------ 287

Local Government--------------------------- 287
Housing------------------------------------ 291
Health------------------------------------- 291
Major Social Problems---------------------- 291

2.1.2.11 Land Use-- 292

2.1.2.12 Paleontological, Archaeological, Historical--------------- 295

Known Sites-- 295
Proposed or Planned Sites or Areas------------------- 296
Potentially Signficiant Areas or Sites--------------- 296
Archaeological Background---------------------------- 296

2.1.2.13 Recreational and Aesthetic Resources--------------------- 298

Recreational Facilities, Areas, and Resources--------- 298
Esthetic, Scenic and Cultural Features--------------- 300

2.1.2.14 Air Quality--- 304

Types of Pollutants---------------------------------- 304
Sources of Pollution--------------------------------- 304
Climatic and Topographic Effects--------------------- 304
Distribution of Air Pollution Along the Proposed Route-- 305

2.1.2.15 Environmental Noise------------------------------------- 306

Ambient Sound Levels--------------------------------- 306

Page

Transmission Properties 307

References 308

3 Environmental Impact of the Proposed Action 321
3.1 Arctic Gas Pipeline Project 321
3.1.2 Canadian Pipeline 321

Introduction and Summary 321

Topography, Geology and Soils 321
Water Resources 321
Vegetation 322
Wildlife 322
Economic Factors 323
Sociological Factors 323
Land Use 323
Archeological and Historic Factors 324
Recreation and Esthetic Factors 324

3.1.2.1 Climate 324

Impact of the Proposed Pipeline System on Climate 324
Impact of Climate on Construction and Operation of the Pipeline System 325

3.1.2.2 Topography 327

Slopes 327
Borrow Pits 348

3.1.2.3 Geology 354

Impact of the Pipeline and Related Structures 354

Disturbances Caused by Construction and Operation of Pipeline North of 60th Parallel 355

Extraction of Natural Construction Materials and Resulting Terrain Scars 355
Drainage Disruption 356
Instability of Slopes 356
Accelerated Erosion 356
Thawing of Permafrost and Effects of a Cold Buried Pipeline 357

Disturbances Caused by Construction and Operation of Pipeline South of 60] North Latitude 358

Extraction of Natural Construction Materials and Resulting Terrain Scars 358
Disruption of Drainage 358
Instability of Slopes 359
Accelerated Erosion 359
Thawing of Permafrost and Effects of a Cold Buried Pipeline 360

Distribution of Potential Geologic Impacts Along the Route 360

Engineering Geology Evaluation Categories 360
Permafrost Categories 365
SPG Index 365

Earthquakes and Active Faults 370

Page

Exploration and Production------------------------ 372

Metallic and Nonmetallic Mineral Deposits-------- 372
Oil and Gas-------------------------------------- 373

3.1.2.4 Soils--- 373

Contamination of Topsoils by Excavation of Subsoils--- 374
Exposure of Wind and Water Erosion------------------ 374
Disruption of Agricultural Activities---------------- 374

3.1.2.5 Water Resources----------------------------------- 375

Impact on Surface Water------------------------------ 375

Surface Water Flow------------------------------- 375

Channel Erosion------------------------------ 375
Icings--------------------------------------- 376
Depletion of Streamflow During Construction- 376
Drainage Disruption-------------------------- 377

Surface Water Quality---------------------------- 378

Change in Suspended-Sediment Concentration-- 378
Introduction of Petroleum and other Toxic Materials---------------------------------- 383
Discharge of Wastes-------------------------- 385

Impact of Proposed Pipeline on Ground Water---------- 385

Ground-Water Flow-------------------------------- 385
Ground-Water Quality----------------------------- 387
Ground-Water Supplies---------------------------- 390

3.1.2.6 Vegetation-- 390

Introduction--- 390
The Yukon and Northwest Territories------------------ 392

Construction------------------------------------- 392
Operations and Maintenance----------------------- 402

Warm Season Emergency Repairs--------------- 402
Fire--- 403
Impact of Atmospheric Pollution on Vegetation------------------------------- 403
Wilderness Quality of Vegetation------------ 406

Abandonment-------------------------------------- 406

The Provinces (South of 60° N)----------------------- 407

Alberta Border (60° N) to Caroline Junction------ 408

Pipeline Right-of-Way----------------------- 408
Winter Roads--------------------------------- 410
Drainage Disruption-------------------------- 410
Emergency Repairs---------------------------- 410
Fire--- 410

Page
Caroline Junction to Kingsgate------------------ 411
Caroline Junction to Monchy--------------------- 411
Impact on Forest Resources---------------------- 411

Conclusions on Impact of the Proposed Route----------- 412

3.1.2.7 Wildlife-- 414

Fishery Resources--------------------------------------- 414

Impact of Increased Turbidity and Siltation------ 414

Construction Phase------------------------- 414
Operation and Maintenance Phase------------ 418

Impact of Stream Blockage----------------------- 418

Construction Phase------------------------- 418
Operation and Maintenance Phase------------ 418

Impact of Reduced Oxygen Levels----------------- 419

Construction Phase------------------------- 419
Operation and Maintenance Phase------------ 419

Impact of Spills of Fuel, Gas and Methanol------- 419

Construction Phase------------------------- 419
Operation and Maintenance Phase------------ 422

Impact of Increased Water Usage----------------- 422

Construction Phase------------------------- 422
Operation and Maintenance Phase------------ 422

Impact of Increased Human Utilization----------- 422

Construction Phase------------------------- 424
Operation and Maintenance Phase------------ 424

Mammals-- 424

Large Herbivores-------------------------------- 424

Caribou------------------------------------ 425
Deer--------------------------------------- 428
Wapiti------------------------------------- 428
Moose-------------------------------------- 428
Pronghorn---------------------------------- 429
Musk Ox------------------------------------ 429
Mountain Sheep----------------------------- 429

Page

Small Herbivores---------------------------------- 430

Beaver and Muskrat------------------------- 430
Mice, Voles, Lemmings and Ground Squirrels-- 431
Rabbits, Hares and Pikas------------------- 431

Carnivores-- 431

Wolf-- 431
Arctic and Red Fox------------------------- 432
Grizzly Bear-------------------------------- 432
Polar Bear---------------------------------- 433
Black Bear---------------------------------- 433
Wolverine----------------------------------- 433
Marten-------------------------------------- 433
Fisher-------------------------------------- 434
Weasels------------------------------------- 434

Insectivores-------------------------------------- 434

Shrews-------------------------------------- 434
Bats-- 434

Marine Mammals------------------------------------ 435

Birds--- 435

Lesser Snow Goose------------------------------ 435
Swans-- 437
Other Waterfowl-------------------------------- 437
Upland Game Birds------------------------------ 439
Shorebirds------------------------------------- 439
Song Birds------------------------------------- 439

Rare and Endangered Species-------------------------- 439

Endangered Species of Birds-------------------- 440

Peregrine Falcon------------------------------- 440
Eskimo Curlew---------------------------------- 441
Whooping Crane--------------------------------- 442

Endangered Species of Mammals------------------ 442

Black-Footed Ferret----------------------------- 442
Northern Kit Fox-------------------------------- 442
Northern Rocky Mountain Wolf-------------------- 442

3.1.2.8 Ecological Considerations----------------------------- 443

Major Ecosystems---------------------------------- 443
Ecosystem Productivity---------------------------- 444

Marine Ecosystems-------------------------------- 444

Freshwater Ecosystems----------------------------- 444

Tundra Ecosystem--------------------------------- 445

Forest-Tundra and Forest Dominated Ecosystems--------- 446
Parkland and Grassland Ecosystem--------------------- 446

Page
Ecosystem Interrelationships------------------------ 446

3.1.2.9 Economic Factors-- 448

Principal Economic Activities------------------------ 448

Primary Direct-------------------------------------- 448
Primary Indirect------------------------------------ 449
Secondary-- 450

Employment-- 450

Direct Gas Pipeline Employment------------------ 451
Indirect Gas Pipeline Employment---------------- 451
Induced Gas Pipeline Employment----------------- 462

Income-- 462
Local Tax Structure and Tax Base-------------------- 463
Economic Trends and Development--------------------- 472

3.1.2.10 Sociological Factors------------------------------------ 473

Population-- 473
Community Structure--------------------------------- 479

Housing-- 479
Services--- 479

Communications-------------------------------- 479
Utilities-------------------------------------- 484
Wholesale and Retail Trade-------------------- 484
Finance-- 484
Community Services---------------------------- 484
Personal Services----------------------------- 484
Services for Businesses----------------------- 485
Tourist Services------------------------------ 485
Contracting and Building--------------------- 485
Government - This group includes the branches of federal------------------------------- 485
Solid Waste Disposal-------------------------- 485

Attitudes of the Residents-------------------------- 486

3.1.2.11 Land Use-- 486
3.1.2.12 Archeological, Historic, and Other Unique Values----------- 487

Destruction of Potential Sites---------------------- 487
Effect on Present and Existing Sites---------------- 488
Increased Accessibility to Potential Sites----------- 489
Increased Number of Known Sites--------------------- 489

3.1.2.13 Recreational and Esthetic Resources------------------------ 490

Recreation Facilities, Areas, and Resources----------- 490
Esthetics--- 491

3.1.2.14 Air Quality--- 492

Exhaust Emissions from Construction Equipment-------- 492
Emissions from Compressor Stations------------------ 493
Dust Due to Construction---------------------------- 494

Page

3.1.2.15 Environmental Noise 494
Effects on Humans 495
Construction Phase 495
Road Traffic 495
Right-of-way Construction 495
Blasting and Vibration 495
Compressor Station Construction 500
Operation Phase 501
Compressor Stations 501
Blowdown 501
Effects on Wildlife 501
Construction Phase 501
Caribou 501
Dall Sheep 504
Grizzly Bears 504
Moose 504
Snow Geese, Canada Geese, White-Fronted Whistling Swans 504
Peregrine Falcons 504
Operation Phase 504
Gas Compressor Stations 504
Aircraft 508
Air Cushion Vehicles (ACV)-1 516
References 519
4 Mitigating Measures Included in the Proposed Action 529
4.1 Arctic Gas Pipeline Project 529
4.1.2 Canadian Pipeline 529
4.1.2.1 Measures to Protect the Environment as Proposed by applicant 530
4.1.2.2 Restoration as Proposed by Applicant 546
4.1.2.3 Emergency Measures as Proposed by Applicant 551
4.1.2.4 Stipulations for Right-ofway Grants, Permits, Leases and Contract Sales Required by the Federal Government 559
Expanded Guidelines for Northern Pipelines 559
Pipelines "Corridor" Guidelines 562
Introduction 562
Purpose and Use of "Corridor" Concept 562

Page

"Corridor" for Trunk Pipelines in Yukon Territory and Mackenzie Valley Region----- 562

Environmental Guidelines------------------------------- 564

Introduction------------------------------- 564
Guidelines: Some Current Environmental Concerns of Government------- 564
Suggested Topics for Response to Environmental Concerns------------------- 566

Social Guidelines--------------------------------------- 569

Introduction------------------------------- 569
Guidelines:-------------------------------- 570

4.1.2.5 Research and Monitoring--------------------------------------- 572
4.1.2.6 Liability and Compensation for Losses--------------------- 573
4.1.2.7 Other Measures Which Could Further Reduce Environmental Impacts-- 573

Training Programs------------------------------------- 573
References--- 574
5 Adverse Environmental Effects Which cannot be avoided should the Proposal be Implemented---------------------- 577
5.1 Arctic Gas Pipeline Project---------------------------------- 577
5.1.2 Canadian Pipeline--- 577
5.1.2.1 What is Adversely Affected and to What Degree------------- 577

Climate--- 577
Topography, Geology and Soils---------------------- 577
Water Resources------------------------------------- 578
Vegetation--- 579
Wildlife--- 580

Fish--- 580
Mammals-- 580
Birds-- 581

Economic Factors------------------------------------ 58q
Sociological Factors-------------------------------- 582
Land Use--- 583
Archeological and Historical Factors--------------- 583
Recreation and Aesthetic Factors------------------- 583
Air Quality--- 584
Environmental Noise--------------------------------- 584

5.1.2.2 Summary of Residual Effects------------------------------ 585

Immediate Project Area--------------------------------- 585
Regional Considerations-------------------------------- 586

5.1.2.3 Impacts In Relation to Resources, Activities and Values---- 586

Resources-- 586
Activities--- 586

Economic and Regional Development--------------- 586
Social--- 587
Recreational and Wildlife Refuges--------------- 587

Values--- 588
Social and Health----------------------------------- 588
Esthetic, Historic and Recreation------------------ 588

Page

6 Relationship Between Local Short-Term Uses of the Environment and the Maintenance and Enhancement of Long-Term Productivities-- 589
6.1 Arctic Gas Pipeline Project---------------------------------- 589
6.1.2 Canadian Pipeline--- 589

6.1.2.1 Definitions of "Long-Term" and "Short-Term"---------------- 589

6.1.2.2 Environmental Values Affected by the Proposed Action------- 589

Climate-- 589
Topography, Geology, and Soils----------------------- 589
Water Resources-------------------------------------- 589
Vegetation--- 590
Wildlife--- 591

Fish--- 591
Mammals-------------------------------------- 591
Birds-- 592

Recreation and Esthetics----------------------------- 592
Air Quality-- 592

6.1.2.3 Restrictions to Future Options and Needs------------------ 593

Land Use--- 593
Acquisition of Mineral Resources--------------------- 593
Availability of Fuel--------------------------------- 593

6.1.2.4 Benefits of Energy Supply Made Available as A Result of the Proposed Action-- 593

7 Irreversible and Irretrievable Commitments of Resources---- 595
7.1 Arctic Gas Pipeline Project-------------------------------- 595
7.1.2 Canadian Pipeline--- 595

7.1.2.1 Damages from Natural Catastrophe or Man-Caused Accidents--- 595

7.1.2.2 Project Structures Unlikely to Be Removed----------------- 595

7.1.2.3 Resources Extraction-------------------------------------- 595

7.1.2.4 Erosion--- 596

7.1.2.5 Destruction of Cultural, Archeological, Aesthetic, Scenic, or Historic Sites-- 596

7.1.2.6 Irreversible and Irretrievable Commitments of Resources---- 596

Wildlife--- 596

7.1.2.7 Irrevocable Changes in Land Use--------------------------- 597

Recreation and Aesthetics---------------------------- 597

7.1.2.8 Commitments of Materials and Human Resources-------------- 597

References--- 599

8 Alternatives to the Proposed Action------------------------ 601
8.1 Alternative Arctic Gas Pipeline Routes--------------------- 601
8.1.2 Canadian Pipeline--- 601

Page

8.1.2.1 Interior Route-- 602

Description of the Existing Environment-------------- 603

Climate-- 603
Topography------------------------------------- 603
geology-- 604

Physiography------------------------------- 604
Bedrock------------------------------------ 605
Surficial Deposits------------------------- 606
Mineral Resources-------------------------- 606
Seismicity--------------------------------- 607
Mass Wasting------------------------------- 607
Erosion------------------------------------ 608
Permafrost--------------------------------- 608

Soils-- 609
Water Resources-------------------------------- 609

Surface Water------------------------------ 609
Ground Water------------------------------- 612

Vegetation------------------------------------- 612

Tundra Formation--------------------------- 612
Forest-Tundra Formation-------------------- 612

Wildlife--------------------------------------- 618

Fish--------------------------------------- 618
Mammals------------------------------------ 619
Birds-------------------------------------- 619

Ecological Considerations---------------------- 619
Economic Factors------------------------------- 620
Sociological Factors--------------------------- 621
Land Use--------------------------------------- 622
Paleontological, Archaeological, and Historic Sites-------------------------------------- 622
Recreation and Aesthetic Resources------------- 623
Air Quality------------------------------------ 623
Environmental Noise---------------------------- 623

Evaluation of the Environmental Impacts-------------- 624

Climate-- 624
Topography------------------------------------- 624
Geology-- 624

Disturbances Caused by Construction and Maintenance of the Proposed Pipeline System---------------------------------- 624
Use of Construction Material and Resulting Terrain Scars--------------------------- 625
Disruption of Surface and Subsurface Drainage--------------------------------- 626
Earthquakes and Active Faults-------------- 628

Page
Thawing and Frost Heave-------------------- 628

Factors Affecting Terrain Reaction----- 628
Time Since Initial Disturbance--------- 629
Frost Heave and Heaving Pressure------- 630

Instability of Slopes Including Cut Slopes-- 630
Accelerated Erosion------------------------ 631
Siltation of Streams----------------------- 631
Impact on Present and Future Mineral Resource Exploration and Production------- 631

Soils-- 632
Water Resources---------------------------------- 632
Vegetation--------------------------------------- 632

Pipeline Right-of-Way---------------------- 633
Winter Roads------------------------------- 633
Drainage Disruption------------------------ 634
Stream Crossings--------------------------- 634
Warm Season Emergency Repairs-------------- 634
Fire--------------------------------------- 634
Air Pollution------------------------------ 635
Ecological Reserves------------------------ 635
Conclusions on Impact of the Interior Route- 636

Wildlife--- 636

Fish--------------------------------------- 636
Mammals------------------------------------ 637
Birds-------------------------------------- 637

Ecological Considerations------------------------ 639
Economic Factors--------------------------------- 640
Sociological Factors----------------------------- 640
Land Use--- 641
Paleontological, Archaeological, and Historic Values--- 641
Recreation and Aesthetic Resources--------------- 641
Air Quality-------------------------------------- 641
Environmental Noise------------------------------ 641

8.1.2.2 Cross Delta Route-- 642

Description of the Existing Environment-------------- 643

Climate-- 643
Topography--------------------------------------- 643
Geology-- 643

Physiography------------------------------- 643
Bedrock------------------------------------ 645
Surficial Deposits------------------------- 645
Mass Movement and Erosion------------------ 646
Permafrost--------------------------------- 646
Mineral Resources-------------------------- 647
Seismicity--------------------------------- 647

Page

Soils-- 647
Water Resources------------------------------ 647

    Surface Water---------------------------- 647
    Ground Water----------------------------- 648

Vegetation----------------------------------- 648

    Herbaceous Coastal Tundra---------------- 648
    Low Shrub-Heath Tundra------------------- 649
    Forest-Tundra---------------------------- 649

Wildlife------------------------------------- 650

    Fish------------------------------------- 650
    Mammals---------------------------------- 650
    Birds------------------------------------ 650

Ecological Considerations-------------------- 651
Social and Economic Factors------------------ 651
Land Use------------------------------------- 652
Paleontological, Archaeological, and Historical-- 652
Recreation and Esthetic Resources------------ 652

Evaluation of the Environmental Impacts------ 653

Climate-------------------------------------- 653
Topography----------------------------------- 653
Geology-------------------------------------- 653
Water Resources------------------------------ 654
Vegetation----------------------------------- 654
Wildlife------------------------------------- 658

    Fish------------------------------------- 659
    Mammals---------------------------------- 659
    Birds------------------------------------ 660
    Wildlife Impact Summary------------------ 660

Ecological Considerations-------------------- 660
Social and Economic Factors------------------ 662
Paleontological, Archaeological, Historical------ 663
Recreation and Esthetic Resources------------ 663

8.1.2.3 Babbage Bight Corridor and LNG Export Terminal Site-------- 664

Description of the Existing Environment------ 664

Climate-------------------------------------- 664
Topography----------------------------------- 664
Geology-------------------------------------- 665

    Mineral Resources------------------------ 665

Water Resources------------------------------ 665
Vegetation----------------------------------- 665
Wildlife------------------------------------- 665
Ecological Considerations-------------------- 666
Economic Factors----------------------------- 666
Sociological Factors------------------------- 666
Land Use------------------------------------- 666

Page
Archaeological and Historic Values--------------- 666
Recreation and Aesthetic Resources--------------- 667
Air Quality-------------------------------------- 667
Environmental Noise------------------------------ 667

Evaluation of the Environmental Impacts-------------- 667

Climate-- 667
Topography, Geology and Soils-------------------- 668

Mineral Resources---------------------------- 668

Water Resources---------------------------------- 668
Vegetation--------------------------------------- 668
Wildlife--- 668
Ecological Consideration------------------------- 669
Economic Factors--------------------------------- 669
Sociological Factors----------------------------- 669
Land Use--- 669
Archaeological and Historic Values--------------- 669
Recreation and Aesthetic Values------------------ 670
Air Quality-------------------------------------- 670
Environmental Noise------------------------------ 670

8.1.2.4 Fort Yukon Corridor------------------------------------- 670

Description of the Existing Environment-------------- 671

Climate-- 671
Topography--------------------------------------- 671
Geology-- 671

Physiography--------------------------------- 671
Bedrock, Surfical Deposts, Permafrost, Mass Wasting---------------------------------- 676
Mineral Resources---------------------------- 683
Seismicity----------------------------------- 683

Soils-- 685
Water Resources---------------------------------- 685

Ground Water--------------------------------- 685

Vegetation--------------------------------------- 689

Richards Island to Fort McPherson------------ 689
Fort McPherson to North Klondike River------- 689
Alaska-Yukon Border to Pelly Crossing-------- 690
Pelly Crossing to Watson Lake---------------- 690
Watson Lake to Windfall---------------------- 690

Wildlife--- 691

Fish--- 691
Mammals and Birds---------------------------- 691

Ecological Considerations------------------------ 693
Economic Factors--------------------------------- 693

Page

Sociological Factors---------------------------- 694
Land Use-- 695
Archaeological and Historic Values--------------- 695
Recreation and Esthetic Resources---------------- 695
Air Quality------------------------------------- 696
Environmental Noise----------------------------- 696

Evaluation of the Environmental Impacts--------------- 697

Climate--- 697
Topography-------------------------------------- 697
Geology--- 697

Mineral Resources-------------------------- 702

Soils--- 702
Water Resources--------------------------------- 703
Vegetation-------------------------------------- 703

Wilderness and Ecological Reserves---------- 704
Endangered Plant Species-------------------- 704
Corridor Segment Impacts-------------------- 704
Major Plant Communities Affected------------ 705

Wildlife-- 706

Fish--------------------------------------- 706
Mammals and Birds-------------------------- 706

Ecological Considerations----------------------- 708
Economic Factors-------------------------------- 708
Sociological Factors---------------------------- 709
Land Use-- 710
Archeological and Historic Values--------------- 710
Recreation and Esthetic Resources--------------- 710
Air Quality------------------------------------- 711
Environmental Noise----------------------------- 711

8.1.2.5 Fairbanks Corridor-- 711

Description of the Existing Environment-------------- 712

Climate--- 712
Topography-------------------------------------- 712
Geology--- 712

Physiography------------------------------- 712
Bedrock------------------------------------ 715
Surficial Deposits------------------------- 718
Mineral Resources-------------------------- 722
Seismicity--------------------------------- 722
Mass Wasting------------------------------- 723
Erosion------------------------------------ 725
Permafrost--------------------------------- 727

Soils--- 728
Water Resources--------------------------------- 728

Page

Surface Water---------------------------------- 728
Ground Water----------------------------------- 729

Vegetation--- 733

Pelly Crossing to Whitehorse--------------- 733
Alaska-Yukon Border to Watson Lake---------- 733
Haines Option Corridor-------------------- 733

Wildlife--- 734

Fish-- 734
Mammals and Birds------------------------- 734

Ecological Considerations---------------------- 735
Economic Factors-------------------------------- 735
Sociological Factors---------------------------- 736
Land Use--- 737
Paleontological, Archaeological, and Historic---- 737
Recreation and Esthetic Resources---------------- 737
Air Quality--------------------------------------- 738
Environmental Noise--------------------------- 738

Evaluation of the Environmental Impacts-------------- 738

Climate--- 738
Topography-- 739
Geology--- 739

Use of Construction Materials--------------- 739
Drainage Disruption------------------------- 741
Disposal of Excess Spoil-------------------- 743
Thawing of Permafrost----------------------- 744
Accelerated Erosion and Mass Wasting-------- 744
Hazards to the Pipeline-------------------- 745
Mineral Resources--------------------------- 747

Soils--- 747
Water Resources----------------------------------- 748
Vegetation-- 748

Corridor Segment Impacts------------------- 748
Major Plant Communities Affected----------- 749

Wildlife-- 750

Fish-- 750
Mammals and Birds--------------------------- 750

Ecological Considerations----------------------- 751
Economic Factors--------------------------------- 751
Sociological Factors----------------------------- 751
Land Use-- 752
Paleontological, Archaeological, and Historic---- 752
Recreation and Aesthetic Resources-------------- 752
Air Quality--------------------------------------- 753
Environmental Noise------------------------------ 753

8.1.2.6 Offshore Corridor--- 753
8.1.2.7 Southern Canada Corridors------------------------------ 753

Page
Description of the Existing Environment--------------- 754

Climate--- 754
Topography-- 754

Liard River-Wolf Lake Corridor-------------- 755
Wolf Lake-Emrson Corridor------------------- 756
Wolf Lake-Crowsnest Corridor---------------- 756
Dome and Brandon Corridors------------------ 757

Geology--- 757

Physiography-------------------------------- 757
Bedrock------------------------------------- 760
Surficial Deposits-------------------------- 761
Mineral Resources--------------------------- 764
Seismicity---------------------------------- 765
Erosion and Slope Stability----------------- 765
Permafrost---------------------------------- 766

Soils--- 767
Water Resources----------------------------------- 767

Surface Water------------------------------- 767
Ground Water-------------------------------- 772

Vegetation-- 773

Liard River-Wolf Lake Corridors------------- 773
Wolf Lake-EMerson Corridor------------------ 774
Wolf Lake-Crowsnest Corridor---------------- 774
Dome and Brandon Corridors------------------ 776

Wildife--- 776

Fish-- 776
Mammals and Birds--------------------------- 776

Economic Factors---------------------------------- 777
Sociological Factors------------------------------ 778
Land Use-- 778
Paleontological, Archaeological, and Historic---- 778
Recreation and Aesthetic Resources--------------- 778
Air Quality--------------------------------------- 779
Environmental Noise------------------------------- 779

Evaluation of the Environmental Impact--------------- 779

Climate--- 779
Topography-- 779

Mineral Resources--------------------------- 779

Soils--- 780
Water Resources----------------------------------- 780

Page
Vegetation------------------------------------ 780

Wolf Lake Corridors------------------------ 780
Dome and Brandon Corridors----------------- 781

Wildlife-------------------------------------- 782
Ecological Considerations---------------------- 782
Economic Factors------------------------------- 782
Sociological Factors---------------------------- 783
Land Use--------------------------------------- 783
Paleontological, Archaeological, and Historic---- 783
Recreation and Esthetic Resources--------------- 783
Air Quality------------------------------------ 783
Environmental Noise----------------------------- 783

8.1.2.8 Alternative of 42-inch Supply Lines---------------------- 784

Description of the Action---------------------------- 784
Evaluation of the Environmental Impacts-------------- 785

8.1.2.9 Summary of Impacts for All Alternatives------------------ 785

Introduction-- 785
Estimated Facilities---------------------------------- 785
Topography and Geology------------------------------- 786

Proposed Route---------------------------------- 786
Interior Route---------------------------------- 789
Cross Delta Route------------------------------- 793
Babbage Bight Corridor-------------------------- 793
Fort Yukon Corridor----------------------------- 793
Fairbanks Corridor------------------------------ 798
Haines Option Corridor-------------------------- 803
Wolf Lake Corridor------------------------------ 803
Dome and Brandon Corridors---------------------- 808
Mineral Resources------------------------------- 811

Water Resources--------------------------------------- 812
Vegetation-- 812
Wildlife-- 813

Fish-- 813
Mammals--- 813
Birds--- 813

Archeology-- 815
Social and Economic Factors--------------------------- 815
Recreation-- 816

References-- 817

Foldouts--Bound in Separate Volume

LIST OF FIGURES

Figure	Title	Page
1.1.2-1	Proposed Canadian and Alaskan pipelines for arctic gas and connections to southern Canadian and U.S. pipelines--	4
1.1.2.2-1	Locations of pipelines and facilities----------------	829
1.1.2.3-1	Generalized design of conventional below-grade mode of construction--	9
1.1.2.3-2	Typical compressor station layout for 30,000-horsepower compressor and 17,000-horsepower refrigeration plant	16
1.1.2.3-3	Diagrammatic representation of compressor station functions and components as they would evolve during development of the proposed system-----------------	17
1.1.2.3-4	Western Canada showing locations of existing major highways that would be used to provide access to parts of the proposed pipeline system--------------	21
1.1.2.5-1	Construction spreads and schedule for proposed pipeline construction--------------------------------	33
1.1.2.5-2	Station construction schedule------------------------	34
1.1.2.6-1	Cross-section configuration of the proposed right-of-way at the time of pipe lowering-------------------	40
1.1.2.6-2	Construction manpower requirements-------------------	45
1.1.2.7-1	Conceptual diagram of Gas Control System-------------	46
1.1.2.7-2	Proposed operations and maintenance districts--------	48
2.1.2.2-1	Index map of proposed route north of 60° N latitude---	64
2.1.2.2-2	Index map of proposed route south of 60° N latitude---	65
2.1.2.2-3	Topographic map showing proposed pipeline route--Prudhoe Bay Supply Line, Milepost 279-389-----------	831
2.1.2.2-4	Topographic map showing proposed pipeline route--Prudhoe Bay Supply Line, Milepost 279-389-----------	833
2.1.2.2-5	Topographic map showing proposed pipeline route--Prudhoe Bay Supply Line, Milepost 389-492-----------	835
2.1.2.2-6	Topographic map showing proposed pipeline route--Richards Island Supply Line, Milepost 0-73, and Parsons Lake Lateral--------------------------------	837
2.1.2.2-7	Topographic map showing proposed pipeline route--Richards Island Supply Line, Milepost 73-143, and Main Line, Milepost 126-147------------------------	839
2.1.2.2-8	Topographic map showing proposed pipeline route--	

Page
Main Line, Milepost 147-223------------------------ 841

2.1.2.2-9 Topographic map showing proposed pipeline route--
Main Line, Milepost 223-326------------------------ 843

2.1.2.2-10 Topographic map showing proposed pipeline route--
Main Line, Milepost 326-413------------------------ 845

2.1.2.2-11 Topographic map showing proposed pipeline route--
Main Line, Milepost 413-511------------------------ 847

2.1.2.2-12 Topographic map showing proposed pipeline route--
Main Line, Milepost 511-579------------------------ 849

2.1.2.2-13 Topographic map showing proposed pipeline route--
Main Line, Milepost 579-668------------------------ 851

2.1.2.2-14 Topographic map showing proposed pipeline route--
Main Line, Milepost 668-746------------------------ 853

2.1.2.2-15 Topographic map showing proposed pipeline route--
Main Line, Milepost 746-821------------------------ 855

2.1.2.2-16 Topographic map showing proposed pipeline route--
Main Line, Milepost 821-895------------------------ 857

2.1.2.2-17 Topographic map showing proposed pipeline route--
Main Line, Milepost 895-967------------------------ 859

2.1.2.2-18 Topographic mpa showing proposed pipeline route--
Main Line, Milepost 967-1037----------------------- 861

2.1.2.2-19 Topographic map showing proposed pipeline route--
Main Line, Milepost 1037-1108---------------------- 863

2.1.2.2-20 Topographic map showing proposed pipeline route--
Main Line, Milepost 1108-1184---------------------- 865

2.1.2.2-21 Topographic map showing proposed pipeline route--
Main Line, Milepost 1184-1261---------------------- 867

2.1.2.2-22 Topographic map showing proposed pipeline route--
Main Line, Milepost 1261-1352---------------------- 869

2.1.2.2-23 Topographic map showing proposed pipeline route--
Main Line, Milepost 1352-1426---------------------- 871

2.1.2.2-24 Topographic map showing proposed pipeline route--
Main Line, Milepost 1426-1430, and Moncny Delivery
Line, Milepost 0-45-------------------------------- 873

2.1.2.2-25 Topographic map showing proposed pipeline route--
Monchy Delivery Line, Milepost 45-142-------------- 875

2.1.2.2-26 Topographic map showing proposed pipeline route--
Monchy Delivery Line, Milepost 142-235------------- 877

2.1.2.2-27 Topographic map showing proposed pipeline route--
Monchy Delivery Line, Milepost 235-305------------- 879

2.1.2.2-28 Topographic map showing proposed pipeline route--

Page

Monchy Delivery Line, Milepost 305-394-------------- 881

2.1.2.2-29 Topographic map showing proposed pipeline route--Kingsgate Delivery Line, Milepost 0-68-------------- 883

2.1.2.2-30 Topographic map showing proposed pipeline route--Kingsgate Delivery Line, Milepost 68-185------------ 885

2.1.2.2-31 Topographic map showing proposed pipeline route--Kingsgate Delivery Line, Milepost 185-281----------- 887

2.1.2.3-1 Selected physiographic provinces and subprovinces north of 60° N latitude----------------------------- 73

2.1.2.3-2 Selected physiographic provinces and subprovinces south of 60° N latitude----------------------------- 74

2.1.2.3-3 Bedrock geology in the region of the proposed route north of 60° N latitude----------------------------- 86

2.1.2.3-4 Bedrock geology in the region of the proposed route south of 60° N latitude----------------------------- 88

2.1.2.3-5 Surficial deposits in the region of the proposed route north of 60° N latitude----------------------------- 92

2.1.2.3-6 Surficial deposits in the region of the proposed route south of 60° N latitude----------------------------- 102

2.1.2.3-7 Permafrost map north of 60° N latitude--------------- 127

2.1.2.3-8 Permafrost map south of 60° N latitude--------------- 128

2.1.2.4-1 Soils of Canada crossed by the proposed route--------- 134

2.1.2.5-1 Drainage basins and selected place names in the region of the proposed route north of 60° N latitude------- 146

2.1.2.5-2 Drainage basins and selected place names in the region of the proposed route south of 60° N latitude------- 147

2.1.2.5-3 Hydrographs showing ration of mean monthly flow to mean annual flow------------------------------------- 157

2.1.2.5-4 Chemical quality of typical surface waters of western Canada--- 159

2.1.2.5-5 Map of hardness of surface waters in western Canada--- 160

2.1.2.5-6 Suspended sediment concentration in rivers of western Canada, 1972--------------------------------------- 161

2.1.2.5-7 Ground-water regions of western Canada--------------- 178

2.1.2.6-1 Vegetation formations crossed by the proposed route--- 889

2.1.2.6-2 Selected physiographic provinces and subprovinces north of 60° latitude------------------------------- 186

2.1.2.6-3 Vegetation formations crossed by the proposed route north of 60° N latitude---------------------------- 187

		Page
2.1.2.6-4	Selected physiographic provinces and subprovinces south of 60° N latitude----------------------------	198
2.1.2.6-5	Vegetation formations and dominant species of major component communities crossed by the proposed route south of 60° N latitude----------------------------	891
2.1.2.7-1	Principal rivers of the proposed route----------------	206
2.1.2.7-2	Drainage basins and selected place names in the region of the proposed north of 60° N latitude------	207
2.1.2.7-3	Drainage basins and selected place names in the region of the proposed south of 60° N latitude------------	208
2.1.2.9-1	Study region, sub-regions, and communities along the proposed route--------------------------------------	250
2.1.2.9-2	Highway map of Yukon Territory and Northwest Territories--	252
2.1.2.9-3	Highway map of Alberta and parts of adjacent British Columbia and Saskatchewan--------------------------	253
2.1.2.10-1	Alberta Census Divisions, 1972-----------------------	271
2.1.2.10-2	Southwestern Saskatchewan population distribution, 1966--	274
2.1.2.10-3	Location map of communities in Yukon Territory and Northwest Territories------------------------------	275
2.1.2.13-1	Zones of significantly different visual and esthetic character, Alaska-Yukon border to 60° N latitude----	301
2.1.2.13-2	Zones of significantly different visual and esthetic character, 60° N latitude to 49° N latitude---------	302
3.1.2.3-1	Graph of SPG Index, with potential for geologic impacts along the Prudhoe Bay Supply Line and the Richards Island Supply Line (including the Parsons Lake Lateral)--	893
3.1.2.3-2	Graph of SPG INdex, with potential for geologic impacts, along the Main Line north of 60° N latitude (Travaillant Lake Junction to Saline River)---------	895
3.1.2.3-3	Graph of SPG Index, with potential for geologic impacts, along the Main Line north of 60° N latitude (Saline River vicinity to 60° N latitude)-----------	897
3.1.2.3-4	Graph of SPG Index, with potential for geologic impacts, along the Main Line south of 60° N latitude (60° N latitude to McLeod River vicinity)-----------	899
3.1.2.3-5	Graph of SPG Index, with potential for geologic impacts, along the Main Line south of 60° N latitude (McLeod River to Caroline Junction) and along the Kingsgate Delivery Line------------------	901
3.1.2.3-6	Graph of SPG Index, with potential for geologic	

Page
impacts, along the Monchy Delivery Line------------ 903

3.1.2.5-1a A ground icing caused by a plowed highway------------ 386

3.1.2.5-1b The effect of a cold pipeline will be to initiate new ground icings in areas where surficial sediments are water saturated and permeable and where there are unfrozen zones below the active layer---------- 386

3.1.2.5-2 Schematic drawing of late summer conditions showing thermokarst development along a chilled gas pipeline-- 388

3.1.2.5-3a Aufeis deposits may develop where the pipeline crosses streams which are underlain by permeable saturated sediments. (Schematic)---------------------------- 389

3.1.2.5-3b Ground ice may develop in vicinity of pipeline in areas underlain by fine-grained, silty soils. (Schematic)--------------------------------------- 389

3.1.2.6-1 Location of proposed Canadian Arctic Wildlife Range and International Biological Program ecological reserves--- 401

3.1.2.7-1 Seasonal movements of Porcupine caribou herd---------- 426

3.1.2.15-1 Construction equipment noise ranges------------------ 498

8.1.2-1 Alternative pipeline routes and corridors and the proposed route in Alaska and western Canada--------- 905

8.1.2-2 Alternative pipeline routes and corridors and the proposed route in southern Canada------------------ 907

8.1.2.1-1 Interior Route--Alaska-Yukon border to Fort McPherson, N.W.T.--- 909

8.1.2.1-2 Vegetation formations crossed by alternative pipeline routes and corridors-------------------------------- 911

8.1.2.1-3 Selected physiographic provinces and subprovinces north of 60° N latitude------------------------------------ 613

8.1.2.2-1 Alternative pipeline routes, MacKenzie Delta area----- 913

8.1.2.4-1 Fort Yukon Corridor--Alaska-Yukon border to Watson Lake, Y.T.-- 915

8.1.2.4-2 Fort Yukon and Fairbanks Corridors, Richards Island Supply Line--Campbell Lake to North Klondike River-- 917

8.1.2.4-3 Fort Yukon Corridor--Watson Lake, Y.T., to Windfall, Alberta--- 919

8.1.2.4-4 Index map showing topographic quadrangles crossed by the Fort Yukon Corridor---------------------------- 672

8.1.2.4-5 Index map of geological reports bearing on the route of the Fort Yukon Corridor------------------------ 673

Page

8.1.2.4-6 Vegetation formations and dominant species of major component communities crossed by alternative corridors south of 60° N latitude------------------ 921

8.1.2.5-1 Fairbanks Corridor--Alaska-Yukon border to Watson Lake, Y.T.-- 923

8.1.2.5-2 Fairbanks Corridor, Richards Island Supply Line--Mouth of North Klondike River to Whitehorse, Y.T.--------- 925

8.1.2.5-3 Haines Option Corridor------------------------------ 925

8.1.2.6-1 Offshore Corridor and proposed route in northern Alaska and Yukon Territory---------------------------------- 927

8.1.2.7-1 Liard River-Wolf Lake Corridor----------------------- 920

8.1.2.7-2 Wolf Lake-Emerson Corridor--Wolf Lake to Quill Lakes-- 931

8.1.2.7-3 Wolf Lake-Emerson Corridor--Quill Lakes to Emerson---- 933

8.1.2.7-4 Wolf Lake-Crowsnest Corridor------------------------- 935

8.1.2.7-5 Moose Jaw, Dome, and Brandon segments---------------- 937

LIST OF TABLES

Table Title

1.1.2.2-1 Length and orientation of Canadian Arctic Gas Pipeline System by segments---------------------------------- 6

1.1.2.3-1 Summary of potential pipe buoyancy conditions determined by terrain type analysis of the proposed route--- 11

1.1.2.3-2 Summary of erosion control measures for the proposed route determined by terrain type analysis----------- 12

1.1.2.3-3 Number of compressor stations required by operating year-- 15

1.1.2.3-4 Types of roads by line segment and construction spread 22

1.1.2.3-5 Gravel quantities and uses for segments of the proposed pipeline system-------------------------------- 26

1.1.2.3-6 Location, time, and duration of occupancy of pipeline construction camps--------------------------------- 28

1.1.2.4-1 Land requirements (acres) for proposed pipeline system 31

1.1.2.6-1 Generalized sequence of construction procedures for buried gas pipeline---------------------------------- 37

1.1.2.7-1 Estimated personnel required for maintenance by operating district and skill type in fifth operating year-- 49

1.1.2.7-2 Estimated ground transportation and work equipment

Page

for maintenance purposed, by district 50

1.1.2.7-3 Anticipated aircraft requirements 51

2.1.2.2-1 Quantitative equivalents of descriptive slope terms 63

2.1.2.3-1 Attributes of sedimentary basins or provinces related to proposed route 113

2.1.2.3-2 Some engineering properties of rock units likely to be subject to slope instability 119

2.1.2.3-3 Some engineering properties of surficial deposits which may be subject to slope instability 122

2.1.2.4-1 Estimated properties of soils along the proposed route 136

2.1.2.5-1 Major rivers crossed by the proposed route 148

2.1.2.5-2 Summary of selected streamflow records along the proposed route 150

2.1.2.5-3 Water quality data for northern Yukon Territory, July to October, 1971 162

2.1.2.5-4 Some physical and chemical characteristics of water bodies sampled March 16-26, 1972 163

2.1.2.5-5 Suspended-sediment data for station number 10MD001, Firth River near mouth 165

2.1.2.5-6 Water-quality data for Mackenzie mainstem rivers and streams, 1971-72 168

2.1.2.5-7 Rates of transport of dissolved elements from Mackenzie watersheds 169

2.1.2.5-8 Mean number of invertebrates per artificial substrate in rivers of similar latitude in eastern and western drainages into the Mackenzie River 171

2.1.2.5-9 Ranges of concentrations of total suspended sediment and Secchi visibility for major Mackenzie mainstem rivers and streams, 1971-72 172

2.1.2.5-10 Discharge rates, TDS contents, and water temperature for springs with associated open water and aufeis deposits 181

2.1.2.5-11 Summary of chemical quality for selected springs and wells in the vicinity of the proposed route 183

2.1.2.6-1 Estimated mileage of proposed pipeline right-of-way crossing major plant communities 189

2.1.2.6-2 Distribution of plant communities in the Low Shrub-Heath Tundra, Richards Island-Tuktoyaktuk region, N.W.T. 192

2.1.2.6-3 Distribution of plant communities (percent) in the northern Yukon interior and coastal mountains 193

Page

2.1.2.6-4 Distribution of plant community types in the Forest-Tundra between Normal Wells and Travaillant Lake along the Mackenzie Valley-------------------- 194

2.1.2.6-5 Distribution of flant community types in the Forest-Tundra between the Alberta-N.W.T. boundary and Normal Wells along the proposed route----------- 197

2.1.2.7-1 Fish species present in the Beaufort Sea (Arctic Ocean) drainage--- 209

2.1.2.7-2 Major tributaries of the Mackenzie River------------- 211

2.1.2.7-3 Fish present in the Mackenzie River drainage and their distributions north and south of 60° N latitude----- 212

2.1.2.7-4 Summary of spawning and nursery areas, Mackenzie River system--- 214

2.1.2.7-5 Domestic catches of fish at locations in the Mackenzie Valley during 1972-------------------------------- 217

2.1.2.7-6 Fish found in the Saskatchewan River drainage in Alberta-- 218

2.1.2.7-7 Fish found in the Missouri River drainage in Alberta-- 220

2.1.2.7-8 Fish found in the Columbia River drainage------------ 221

2.1.2.7-9 Mammal species known or possibly occurring along segments of the proposed route and marine species that might be influenced directly or indirectly by construction, operation or other activities associated with building the pipeline-------------- 223

2.1.2.7-10 Bird species known or expected along segments of proposed route; includes winter areas-------------- 229

2.1.2.9-1 Study region employment, 1972------------------------ 251

2.1.2.9-2 Working age population by sub-region and community, 1971--- 256

2.1.2.9-3 Study region estimated income levels by community, 1973--- 258

2.1.2.9-4 Study region personal income from all sources, 1970--- 259

2.1.2.9-5 Sources of income by sub-region, 1970---------------- 261

2.1.2.9-6 Municipal taxes and assessments on a typical three-bedroom house, selected communities, 1972----- 263

2.1.2.9-7 Government of the Northwest Territories operation and capital expenditures, 1969-1972-------------------- 264

2.1.2.10-1 Population growth 1911-1971--Northwest Territories and Canada-- 267

2.1.2.10-2 Estimated 1971 population by sub-region and community- 268

Page

2.1.2.10-3 Population growth and distribution, Alberta---------- 270

2.1.2.10-4 Large centers of population in Alberta--------------- 270

2.1.2.10-5 Area and density of population census divisions, Alberta, 1956, 1961, 1966, and 1971---------------- 272

2.1.2.10-6 Housing stock in Northwest Territories--------------- 278

2.1.2.10-7 Enumeration area populations, 1961-1966-1971, by sex and ethnic origin----------------------------- 283

2.1.2.10-8 Ethnic composition of total study region population, 1931-1971--- 284

2.1.2.10-9 Population by age group and sex, Northwest Territories: 1951-1971---------------------------- 285

2.1.2.10-10 Projected population by sub-region, 1975-1985--without the pipeline--------------------------------------- 286

2.1.2.10-11 Projected total and male working age population in the study region, 1971-1985--without the pipeline------ 288

2.1.2.10-12 Ethnic composition of projected male working age population in the study region, selected years--without the pipeline------------------------- 289

2.1.2.10-13 Low projection of working age population, 1971, 1976, 1981--- 290

3.1.2.2-1 Location of slopes greater than 5% along the Prudhoe Bay Supply Line------------------------------------ 329

3.1.2.2-2 Location of slopes greater than 5% along the Richards Island Supply Line and the Parsons Lake Lateral Line 330

3.1.2.2-3 Location of slopes greater than 5% along the Main Line north of 60° N latitude---------------------------- 331

3.1.2.2-4 Location of slopes greater than 5% along the Main Line south of 60° N latitude----------------------- 332

3.1.2.2-5 Location of slopes greater than 5% along the Monchy Delivery Line------------------------------------- 333

3.1.2.2-6 Location of slopes greater than 5% along the Kingsgate Delivery Line--------------------------- 334

3.1.2.2-7 Location of those slopes greater than 5% that are higher than 100 feet----------------------------- 335

3.1.2.2-8 Summary of steepness and length of slopes along the Prudhoe Bay Supply Line--------------------------- 341

3.1.2.2-9 Summary of steepness and length of slopes along the Richards Island Supply Line and the Parsons Lake Lateral Line--- 342

3.1.2.2-10 Summary of steepness and length of slopes along the Main Line north of 60° N latitude----------------- 343

Page

3.1.2.2-11 Summary of steepness and length of slopes along the Main Line south of 60° N latitude------------------ 344

3.1.2.2-12 Summary of steepness and length of slopes along the Monchy Delivery Line------------------------------ 345

3.1.2.2-13 Summary of steepness and length of slopes along the Kingsgate Delivery Line---------------------------- 346

3.1.2.2-14 Summary of slopes greater than 5% along all parts of proposed route------------------------------------- 347

3.1.2.2-15 Borrow pits along the Prudhoe Bay Supply Line--------- 349

3.1.2.2-16 Borrow pits along the Richards Island Supply Line----- 350

3.1.2.2-17 Borrow pits along the Main Line north of 60° N latitude--- 351

3.1.2.2-18 Summary of borrow pit data-------------------------- 353

3.1.2.3-1 Engineering geology categories into which combinations of bedrock units and surficial deposits units found along the proposed route have been placed----------- 362

3.1.2.3-2 Distribution of engineering geology categories along the proposed route---------------------------------- 363

3.1.2.3-3 Summary of engineering geology categories along the proposed route------------------------------------- 364

3.1.2.3-4 Distribution of permafrost categories along the proposed route------------------------------------- 366

3.1.2.3-5 Summary of permafrost categories along the proposed route--- 367

3.1.2.3-6 Components of the SPG Index------------------------- 368

3.1.2.3-7 Summary of SPG Indices for each major part and for the entire proposed route---------------------------- 371

3.1.2.5-1 Summary of impacts---------------------------------- 379

3.1.2.6-1 Areas of vegetation formations affected by the proposed route in Yukon and Northwest Territories--- 391

3.1.2.6-2 Acreage of vegetation types along the proposed route Travaillant Lake Junction to the 60° N latitude----- 394

3.1.2.6-3 Vegetation north of 60° N latitude altered by winter roads and stream crossings------------------------ 397

3.1.2.6-4 Frequency distribution of fires in the District of Mackenzie, N.W.T., and Yukon Territory north of 67° N latitude by size class during 1962-71--------------- 404

3.1.2.6-5 Fire susceptibility for regions along the proposed route-- 405

3.1.2.6-6 Areas of vegetation formations affected by the

Page

proposed route in Alberta, Saskatchewan, and British Columbia-- 409

3.1.2.6-7 Major plant communities (acres) that would be initially committed to the proposed route-------------------- 413

3.1.2.7-1 Waterways north of the 60° N latitude significant to the fish resource---------------------------------- 416

3.1.2.7-2 Dissolved oxygen levels in selected waterways of the Beaufort Sea drainage during the winter of 1973----- 420

3.1.2.7-3 Dissolved oxygen levels in selected waterways of the Mackenzie River drainage during the winter of 1973-- 421

3.1.2.7-4 Anticipated usage of water during pipeline construction-- 423

3.1.2.9-1 Employment in construction of gas pipeline, northern Canada, 1975-1981 (man years)---------------------- 452

3.1.2.9-2 Concentration of men required during peak working periods--- 453

3.1.2.9-3 Employment in construction of gas pipeline by skill category, northern Canada, 1975-1981 (man years)---- 454

3.1.2.9-4 Gas-related industry employment in study region, 1973-1983 (man years)-------------------------------- 455

3.1.2.9-5 Water-transport system employment, 1973-1980 (man years)--- 457

3.1.2.9-6 Gas-related water-transport system employment by sub-region, 1973-1983 (man years)------------------ 458

3.1.2.9-7 Labor requirements for all-weather highway construction--Mackenzie and Dempster Highways, 1973-1977 (man years)------------------------------ 459

3.1.2.9-8 Net indirect employment summary by category, 1973-1983 (man years)------------------------------ 460

3.1.2.9-9 Distribution of indirect employment by sub-regions, 1973-1983 (man years)------------------------------ 461

3.1.2.9-10 Total employment generated by pipeline, gas industry and related developments, 1973-1983 (man years)----- 464

3.1.2.9-11 Permanent employment generated by pipeline and gas-producing industry, 1974-1983 (man years)------- 466

3.1.2.9-12 Estimated increase in annual earnings of Northwest Territories through pipeline employment by occupation (per work; basis, 1970 values)---------- 467

3.1.2.9-13 Estimated increase in annual earnings of northern residents through pipeline employment by occupation (1973 dollars)------------------------- 468

3.1.2.9-14 Estimated gross cash income effect of probable territorial employment on a gas pipeline during

		Page
	profile years of the three major periods of activity (thousands of dollars; basis, 1970 values) -	469
3.1.2.9-15	Income effect of direct territorial pipeline employment (thousands of dollars; basis, 1970 values) ----------	470
3.1.2.9-16	Income effect of indirect territorial pipeline employment (thousands of dollars; basis, 1970 values) --	471
3.1.2.9-17	Territorial taxes-pipeline and ancillary installations	474
3.1.2.9-18	Northwest Territories property tax--pipeline buildings	476
3.1.2.9-19	Territorial fuel tax revenues expected during construction of the proposed pipeline--------------	477
3.1.2.10-1	Total and male working age population in the study region, 1971 and 1981------------------------------	478
3.1.2.10-2	Projection of population and new housing requirements, by sub-region, 1971-1983---------------------------	480
3.1.2.15-1	Communities potentially impacted by truck hauling activities---	496
3.1.2.15-2	Impact of pipeline construction noise on people in Alberta and Saskatchewan---------------------------	499
3.1.2.15-3	Impact of gas compressor station noise on people------	502
3.1.2.15-4	Blowdown noise--------------------------------------	503
3.1.2.15-5	Maximum horizontal distances at which wildlife react to gas compressor station noise--------------------	505
3.1.2.15-6	Maximum land area north of 60° N latitude avoided or having decreased usage by wildlife due to noise emissions from gas compressor stations-------------	507
3.1.2.15-7	Maximum distances at which wild life react to aircraft noise---	509
3.1.2.15-8	Aircraft noise--------------------------------------	510
3.1.2.15-9	Maximum land areas north of 60° N latitude avoided or having decreased usage by wildlife due to noise emissions from pipeline surveillance aircraft-------	511
3.1.2.15-10	Distances at which all snow geese flush in response to Cessna 185 fixed-wing aircraft------------------	514
3.1.2.15-11	Air cushion vehicle (ACV) sound levels---------------	517
3.1.2.15-12	Maximum horizontal distance at which birds flush in reaction to air cushion vehicle noise------------	518
7.1.2.8-1	Constructon resource requirements, in tons------------	598
8.1.2.1-1	Summary of selected streamflow records along the Interior Route--	610

Page

8.1.2.1-2 Distribution of plant communities in the northern Yukon interior and coastal mountains---------------- 614

8.1.2.1-3 Estimated areas of vegetation affected by the Interior Route, Alaska-Yukon border to Fort McPherson-------- 616

8.1.2.1-4 Comparative summary of environmental impact sensitivit for the proposed route and Interior Route for mammal and birds-- 638

8.1.2.2-1 Length and area of right-of-way of Cross-Delta Route affecting various vegetation types--Shingle Point and Richards Island to Thunder River---------------- 656

8.1.2.2-2 Estimated areas of vegetation affected by right-of-way and facilities along the Cross-Delta Route--Shingle Point and Richards Island to Thunder River---------- 657

8.1.2.4-1 Summary of selected streamflow records along the Fort Yukon Corridor---------------------------------- 686

8.1.2.5-1 Summary of selected streamflow records along the Fairbanks Corridor, including the Richards Island Supply Line and the Haines Option Corridor---------- 730

8.1.2.7-1 Summary of selected streamflow records along the Wolf Lake Corridors-- 768

8.1.2.9-1 Numbers of facilities and acreage requirements for proposed route and alternative routes and corridors- 787

8.1.2.9-2 Physical setting, proposed route--------------------- 788

8.1.2.9-3 Potential geologic hazard zones, proposed route------- 790

8.1.2.9-4 Physical setting, Interior Route--------------------- 791

8.1.2.9-5 Potential geologic hazard zones, Interior Route------- 792

Page

8.1.2.9-6 Physical setting, Cross-Delta Route------------------ 794

8.1.2.9-7 Potential geologic hazard zones, Cross-Delta Route---- 795

8.1.2.9-8 Physical setting, Babbage Bight Corridor-------------- 796

8.1.2.9-9 Potential geologic hazard zones, Babbage Bight Corridor--- 797

8.1.2.9-10 Physical setting, Fort Yukon Corridor---------------- 799

8.1.2.9-11 Potential geologic hazard zones, Fort Yukon Corridor-- 800

8.1.2.9-12 Physical setting, Fairbanks Corridor------------------ 801

8.1.2.9-13 Potential geologic hazard zones, Fairbanks Corridor--- 802

8.1.2.9-14 Physical setting, Haines Option corridor------------- 804

8.1.2.9-15 Potential geologic hazard zones, Haines Option Corridor--- 805

8.1.2.9-16 Physical setting, Wolf Lake Corridors---------------- 806

8.1.2.9-17 Potential geologic hazard zones, Wolf Lake Corridors-- 807

8.1.2.9-18 Physical setting, Dome and Brandon Corridors---------- 809

8.1.2.9-19 Potential geologic hazard zones, Dome and Brandon Corridors-- 810

Introduction

This Environmental Impact Statement was prepared as a necessary part of the decision-making process responding to several applications before the Department of the Interior for approval of natural gas pipeline rights-of-way across Federal lands. The applications by companies, or consortia of companies, provide for a natural gas transmission system amounting to 3,850 miles over Federal lands.

One applicant, a consortium doing business in Alaska as the Alaskan Arctic Gas Pipeline Company, has proposed a right-of-way 195 miles long across northern Alaska to Canada. The same consortium, operating in Canada as Canadian Arctic Gas Pipeline, Ltd., has applied to the Department of Indian and Northern Affairs for rights-of-way in Canada which total 2,435 miles. The combined gas transmission system in Canada and the United States thus totals 6,285 miles of right-of-way across very diverse North American environments.

The proposed Canadian segment of the system will receive gas from Prudhoe Bay, Alaska at the Alaska-Yukon border, and carry it southward across the latitudinal extent of western Canada to delivery points in the United States at Kingsgate, British Columbia and Monchy, Saskatchewan.

The magnitude of the total system as proposed, its potential impact on environments, and the necessity of considering optimal alternatives of modes and routes for transmission of natural gas, necessitate analysis of the entire system, including that large and significant portion that lies within another sovereign nation.

The Environmental Impact Statement for the proposed Canadian gas pipeline has been prepared by staff members of the U. S. Department of the Interior pursuant to requirments of Section 102(2)C of the National Environmental Policy Act of 1969 (NEPA). The Act recognizes the worldwide, long-range character of environmental problems and seeks "...to maximize international cooperation in anticipating and preventing a decline in the quality of mankind's world environment."

In applying the NEPA requirement as well as the guidelines for Environmental Impact Statements, issued by the Council on Environmental Quality for the preparation of such statements, the Department of the Interior has been sensitive to the difficulties inherent in attempting to fit the project of another country into a format designed for the United States. Every effort has been made to avoid any inadvertent appearance of criticism of the Canadian Government or any implication of gratuitous advice. For example, the mitigation of environmental effects as controlled by Government receives less rigorous attention than is true for a project in the United States. Problems involving suggestions or recommendations of study or further evaluation are avoided as are all subjects deemed likely to be abrasive.

Through a series of meetings in 1974 between officials of the Canadian Government and of the U.S. Department of the Interior, an understanding was reached with Canada that this statement was necessary. It was further understood that the statement would be based upon documents and data provided by the Applicant and the Canadian Government, that no studies would be done in Canada by the United States, and that no suggestion would be made for additional studies to be accomplished by the Canadian Government. These understandings have been adhered to and no contacts have been made with Canadian Government scientific or engineering counterparts of those preparing this statement except on an official basis through the Canadian Embassy in Washington.

A copy of the first draft of the Draft Environmental Impact Statement was presented to the Canadian Embassy for review and the present report has benefited from the appraisal that resulted. The Department of the Interior, however, assumes sole responsibility for the content and interpretations of the Statement.

1 DESCRIPTION OF THE PROPOSED ACTION

1.1 ARCTIC GAS PIPELINE PROJECT

1.1.2 Canadian Pipeline

The Canadian Arctic Gas Pipeline, Ltd., and the Alaskan Arctic Gas Pipeline Co. propose to construct and operate a pipeline system that will transport 4.5 bcf (billion cubic feet) of natural gas per day from sources in the Prudhoe Bay area of Alaska and the Mackenzie Delta region of Canada to southern Alberta for distribution into existing or proposed pipelines connecting to eastern Canada and the midwestern and western United States (Figure 1.1.2-1). Approximately 195 miles of the proposed system are in Alaska between Prudhoe Bay and the international border; this portion is described in other sections of the Environmental Impact Statement. This section describes the Canadian part of the system, comprising approximately 2,435 miles of pipeline. The description is based on applications and supporting documents submitted to Canadian Governmental authorities by Canadian Arctic Gas Pipeline, Ltd.

Citations to the supporting documents used as the basis for this part of the Impact Statement are presented in the form: (CAGPL, 1974, 8.b.1.4.2, p. 2). "CAGPL" indicates that the report was prepared by or for Canadian Arctic Gas Pipeline, Ltd.; "1974" indicates the year; "8.b.1.4.2" indicates the report section in which the subject is discussed; "p. 2" indicates the page number in that section on which the discussion occurs.

1.1.2.1 Introduction

The Canadian Pipeline is a part of the proposed Alaska Natural Gas Transportation System (ANGTS) which will initially transport 4.50 bcf/d (billion cubic feet per day) of natural gas, 2.25 bcf/d from the Prudhoe Bay Field in Alaska and 2.25 bcf/d from the MacKenzie Delta area of the Northwest Territories, Canada, to industrial and population centers in Canada and the United States. The revised applications from the applicants are based on the assumption that the 2.25 bcf/d from MacKenzie Delta area will be transported to Canadian markets and the 2.25 bcf/d from Prudhoe Bay will be transported to market areas in the United States.

The Canadian Pipeline is proposed by a consortium of companies operating in Canada as the Canadian Arctic Gas Pipeline Limited.

The Canadian Pipeline will transport, at least, natural gas produced from the Prudhoe Bay Field in Alaska and the Richards Island and Parsons Lake Fields in the MacKenzie Delta area.

The Canadian Pipeline system will consist of three supply lines at its northern end: (1) Prudhoe Bay Supply Line, (2) Richards Island Supply Line, and (3) Parsons Lake Lateral. The Main Line extends from the Travaillant Lake Junction to a bifurcation near Caroline, Alberta.

Two delivery lines will extend southeastward and southwestward from the Caroline Junction. The southwestern delivery line will extend to the United States-Canada border near Kingsgate, British Columbia, where it will interconnect with the proposed facilities of Interstate Transmission Associates (Arctic). The southeastern delivery line will extend to the United States-Canada border near Monchy, Saskatchewan, where it will interconnect with the proposed facilities of Northern Border Pipeline Company.

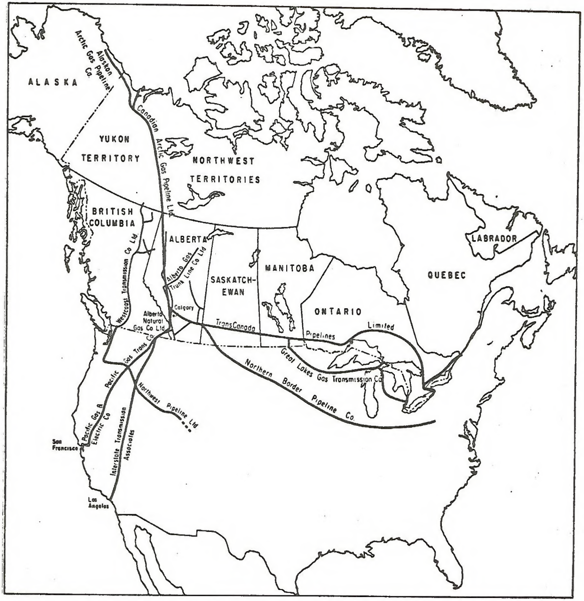

ALASKA
Alaskan Arctic Gas Pipeline Co.
YUKON TERRITORY
NORTHWEST TERRITORIES
Canadian Arctic Gas Pipeline Ltd.
BRITISH COLUMBIA
ALBERTA
SASKATCH-EWAN
MANITOBA
ONTARIO
QUEBEC
LABRADOR
Westcoast Transmission Co Ltd
Alberta Gas Trunk Line Co Ltd
Calgary
Alberta Natural Gas Co Ltd
Pacific Gas Trans Co
TransCanada Pipelines Limited
Great Lakes Gas Transmission Co
Northern Border Pipeline Co.
Northwest Pipeline Ltd
Pacific Gas & Electric Co
Interstate Transmission Associates
San Francisco
Los Angeles

Figure 1.1.2-1 Proposed Canadian and Alaskan pipelines for Arctic gas and connections to southern Canadian and U.S. pipelines

At a point on the southwestern delivery line near the Alberta-British Columbia border, a delivery will be made to ANG (Alberta Natural Gas Company Limited). This company's existing system (106.1 miles in length) will be enlarged and will transport Pacific Gas Transmission Company's (PGT) share of Prudhoe Bay natural gas to a point near Kingsgate, British Columbia, where it will interconnect with the proposed and existing facilities of PGT. ANG has filed an application containing three cases with the National Energy Board. Case I involves a total of 41.3 miles of looping along the existing pipeline; Case II involves looping 87.5 miles of the existing pipeline; and Case III involves 102.2 miles of pipeline and the addition of two compressor units at each of two existing compressor stations. In each case the new pipe will connect with previously installed security loops across the Kootenay River and the Flathead Ridge; Case III will also connect with existing security loop across the Elk River. The designs of the three cases would transport additional volumes of 200, 600 and 1,200 MMcf/d (million cubic feet per day), for Cases I, II, and III, respectively. Case III is comparable in design with the amended application of PGT to the Federal Power Commission in the United States.

The Canadian Main Line can deliver 4.5 bcf/d when fully powered while the delivery and supply lines have greater capacity. The total capacity of connecting facilities applied for also exceeds 4.50 bcf/d. Quantities above this will require additional facilities.

The ultimate capacity of the Main Line (4.5 bcf/d) would serve a residential community with a population of approximately 38.6 million or about 10.1 million residences.

Refer to Overview, Section 1.OV.1, for additional discussion of the ANGTS, and natural gas reserves.

1.1.2.2 Location

The 2,435-mile Canadian portion of the proposed pipeline system crosses southwestern Canada in a southeasterly direction, generally following river valleys and other lowland areas east of the Rocky Mountains. Figure 1.1.2.2-1 (foldout at end of book) shows the proposed pipeline location and sites for metering and compressor stations, stockpiles, and other facilities that will be constructed in the course of development of the gas transportation system.

The pipeline system (Table 1.1.2.2-1) will have three supply lines at its northern end: (1) a 48-inch outside diameter Prudhoe Bay Supply Line that connects with a pipeline from the field at Prudhoe Bay, Alaska, (2) a 48-inch Richards Island Supply Line from the north shore of Richards Island, Northwest Territories, that joins the pipeline from Prudhoe Bay at Travaillant Lake Junction, and (3) a 30-inch lateral from Parsons Lake, Northwest Territories, that joins the pipeline from Richards Island at the Parsons Lake Junction. From Travaillant Lake Junction, the 48-inch main pipeline proceeds south across the Northwest Territories and most of Alberta to a bifurcation near Caroline, north of Calgary. Two delivery lines extend southeastward and southwestward from Caroline Junction. The southwestern pipeline continues to the international border near Kingsgate, British Columbia; the southeastern pipeline continues southeastward to the international border near Monchy, Saskatchewan.

In the fifth operating year, when design capacity will be attained, 4.5 bcf/d (billion cubic feet per day) will be supplied to the pipeline. There will then be five delivery points for the natural gas: 1) on the Main Line near 60° N. latitude, 7.9 percent will be delivered to Westcoast

Table 1.1.2.2-1 Length and orientation of Canadian Arctic Gas Pipeline System by segments

Pipeline System Segment	Length, Miles	Azimuth of Generalized Downstream Direction
Prudhoe Bay Supply Line*	297	130
Richards Island Supply Line	143	150
Parsons Lake Lateral	15	250
Main Line	1,305	155
Kingsgate Delivery Line	281	170, 230
Monchy Delivery Line	394	120
TOTAL	2,435	

*Length of pipeline in Canada only.

Source: CAGRL, 1974, 8.a.2, drawing 4-0214-1004

Transmission Company Limited; 2) on the Kingsgate Delivery Line at the Alberta-British Columbia border, 5.2 percent will be delivered to Alberta Natural Gas Company Limited; 3) at Kingsgate, 10.1 percent will be delivered to the proposed Interstate Transmission Associates (Arctic); 4) on the Monchy Delivery Line, 37.6 percent will be delivered to Trans Canada Pipeline Limited; and, 5) at Monchy, 34.0 percent will be delivered to Northern Border Pipeline Company (CAGPL, 1975, 8.b.1.1, table 1). Approximately 5.2 percent of the total natural gas supply will be used as fuel for compressors and other facilities along the pipeline.

The northern half of the proposed pipeline system does not follow any existing pipelines. In contrast, the southern approximately 1,000 miles make extensive use of existing pipeline routes. South of Hay River crossing (Figure 1.1.2.2-1), the proposed route is adjacent or nearly adjacent to existing rights-of-way except for: 1) approximately 75 miles west of the Swan Hills on the Main Line, 2) approximately 50 miles north of Coleman on the Kingsgate Delivery Line, and 3) approximately 150 miles east of the Alberta-Saskatchewan border on the Monchy Delivery Line.

1.1.2.3 Facilities

The proposed pipeline is a complex system whose physical and operational components will change in time, both in kind and magnitude. Early in the construction phase, for example, the system will consist of roads and airfields, communication facilities and stockpiles of material and equipment. At a later time, these components will be in use facilitating ditching and pipe laying and the construction of the first compressor and refrigeration stations. When the pipeline and first compressor stations are completed, there will be purging and testing, continued construction of compressor stations, and environmental rehabilitation of construction areas, camp sites, and stockpile depots. Even with the first flow of gas, compressor and refrigeration station construction and environmental rehabilitation will continue after surveillance, monitoring, maintenance, and repair have begun. All pipeline and most station construction will be completed in approximately 5 years, and the system will then consist of fully operating physical components abetted by surveillance, monitoring, maintenance and repair activities. Ultimately, however, compressor station capacity might be increased through renewed construction activities and part or all of the pipeline may be looped.

Broad use is taken of the term "facilities" in the following description of the proposed pipeline project in order to include not only the components of the completed and operating pipeline, but also the ephemeral features such as temporary gravel and snow roads, stockpiles, and construction camps. All of these are physical components that will be built if the proposed project is undertaken, and all will interact to some degree with the environment.

Pipeline

The Canadian part of the proposed natural gas transportation system includes approximately 2,435 miles of pipeline. North of Caroline Junction, the Main Line consists of 48-inch outside diameter steel pipe with a wall thickness of 0.72 inch; south of the Junction, on the Monchy Delivery Line, the pipe will be 48 inches outside diameter with a 0.72-inch wall thickness to the delivery point to the Trans Canada Pipeline at the Alberta-Saskatchewan border (figure 1.1.2.2-1). Southward of that point on the Monchy Delivery Line, the pipe will be 48 inches in diameter with a wall thickness of 0.73 inch. Pipe on the Kingsgate Delivery Line will be 36 inches outside diameter with a 0.54-inch wall thickness. Pipe for the Parsons Lake Lateral will be 30 inches in diameter with a wall thickness of 0.45 inch. Specifications for all pipe sizes require minimum yield strengths of 70,000 psi and maximum allowable operating pressures of 1,680 psig. The buried pipe will be designed to withstand temperatures of -10° F north of compressor station M-22, approximately 120 miles north of Peace River; south of M-22 the design temperature would be +25° F. Pipe steel would be high-yield strength API-X-70 having an ultimate yield strength of 82,000 psi or more.

The pipeline will be below ground except at compressor stations. In the conventional buried construction mode design, shown diagrammatically in Figure 1.1.2.3-1, the ditch in which the pipe is buried will typically be 6 to 7 feet wide and about 7 feet deep. If good foundation soils are encountered during ditching, the pipe will be laid directly on the bottom of the trench and backfilled with enough ditch spoil to permit shaping a crown or backfill mound above the preconstruction grade along the pipe centerline. In the conventional mode of construction, the top of the pipe will be a minimum of 2.5 feet below the original ground surface.

The design scour elevation for pipe buried at stream crossings will be determined from an analysis of flood frequency data (CAGPL, 1974, 8.b.1.3.8, p. 57) and the pipe will be weighted to counteract potential buoyant conditions. Either bolt-on weights or articulated reinforced concrete weights will be used.

River crossings along most of the proposed route will employ a single buried pipeline, but at four crossings north of 60° N. latitude dual or tandem crossings will be installed (CAGPL, 1975, 8.b.3, drawings 1E-0232-1001, 1E-0232-1003, 1A-0232-1001, and 1B-0232-1044). The dual crossings are located at Fort Simpson on the Main Line, at the Peel and Mackenzie Rivers on the Prudhoe Bay Supply Line, and at the Mackenzie River on the Richards Island Supply Line. At these crossings, the pipeline on either side of the river will bifurcate within several thousand feet of the river edge. The bifurcation points will be connected by two pipelines buried parallel in their crossings and separated by distances ranging from 300 to 700 feet. Block valves at the bifurcation points will permit gas transmission through either or both pipelines.

Special pipe burial configurations and procedures will be used at locations where geotechnical problems are anticipated. In some cases the need for special burial configurations may be recognized in advance of construction by terrain analysis (CAGPL, 1974, 8.b.1.3.6, p. 39) or other preliminary surveys; in other cases the decision can be made only during the ditching and pipe laying process. In the following paragraphs, some of the modifications of the conventional buried mode are briefly described according to the major geotechnical problems anticipated in constructing the proposed pipeline.

Buoyant forces counteracting the combined weight of the pipe and its contents may cause flotation and upward movement in saturated or liquifiable soils and in places where the pipe is buried in fine-grained sediment beneath streams and lakes. Planned design accommodations include weighting, anchoring, and deeper burial, with or without select high density backfill. In permafrost terrain, it may be possible to adfreeze the pipe to the ditch walls by flooding the trench during the spring months (CAGPL, 1974, 8.b.1.4.2, p. 2).

Differential settlement in soils beneath the pipe can lead to loss of continuous pipe support. Special proposed burial configurations include deeper burial to lay the pipe on more fully consolidated soils, placing

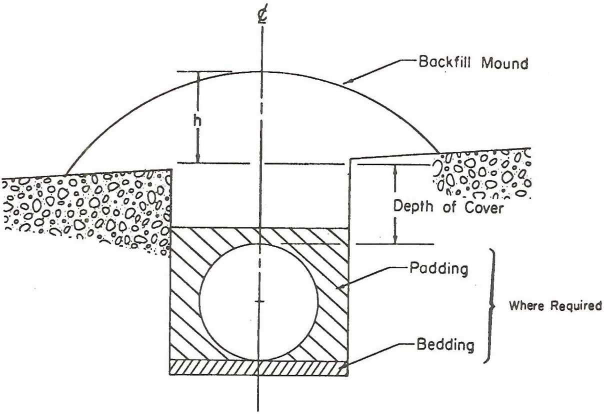


Figure 1.1.2.3-1 Generalized design of conventional below-grade mode of construction

granular bedding beneath the pipe to damp differential settlement, and insulating the pipe to retard thawing and consequent differential settlement of permafrost soils.

The formation of ice lenses near the pipe can produce frost heaving that may affect pipe support. Design alternatives to preclude, forestall, or counteract frost heaving include excavating and replacing frost-susceptible soils, injecting chemical grout into the backfill to retard water migration to freezing areas, insulating the pipeline, and anchoring.

In pipeline segments buried in erodible soils, construction disturbance can initiate erosion either along or across the ditch. Preventive construction measures include installing impermeable soil plugs at intervals along the ditch to interrupt axial flow and forming drainage gaps surfaced with riprap across the backfill mound to confine transverse drainage to nonerodible channels. The backfill mound breaks, spaced 50 to 500 feet apart as required by terrain conditions, will also inhibit ponding against the mound. Ponding on permafrost soils greatly accelerates thawing that can lead to foundation or slope instability.

Preliminary analysis by the Applicant based mainly on aerial photographs, has divided the proposed pipeline route into segments with potential erosion or pipe buoyancy problems. Tables 1.1.2.3-1 and -2 summarize the mileages of each and countermeasures to be taken north and south of 60° N latitude. Potential buoyant conditions may be found in about 30 percent of the proposed route, particularly north of 60° N. latitude. Measures to control potential erosion will be required along nearly all of the route north of 60° N latitude; south of 60° N latitude only about 13 percent of the proposed alignment will need erosion countermeasures.

In addition to pipeline construction proposed by Canadian Arctic Gas Pipeline Limited, some looping would be required on an existing Alberta Natural Gas Pipeline in order to deliver gas to the Pacific Gas Transmission System in the United States. The Alberta Natural Gas Pipeline is 36 inches in diameter, 106.1 miles long, and was built in 1961 between Kingsgate, B. C., on the U.S.-Canada border and the Alberta-British Columbia border at the point of entry of the proposed CAGPL pipeline. Plans for the looping have been made in anticipation of three potential delivery rates: 1) to transmit an additional 200 MMcf/d (million cubic feet per day), 41.3 miles of new 36-inch pipeline would be constructed; 2) to transmit an additional 600 MMcf/d, 87.5 miles of new pipeline would be required; and 3) to transmit an additional 1,200 MMcf/d, 102.2 miles of new pipeline would be built. This new construction would occur within the existing cleared right-of-way. Major river crossings on the existing Alberta Gas Line are double crossings and could adequately transmit gas at increased rates without construction of new crossings.

Compressor and Refrigeration Stations

The design of the proposed pipeline system calls for 36 compressor stations to be brought on stream progressively during the first 5 operating years to attain full throughput capacity. The Main Line requires 31 stations spaced approximately 50 miles apart; the remaining 5 will be distributed along the supply and delivery laterals. Fourteen additional stations will be added to the supply and delivery lines at a future, unspecified date. Of the first 36 compressor stations, the 15 north of Fort Simpson include refrigeration plants to cool the gas to temperatures below 16° F. The distribution of the stations over the major segments of the proposed system and the operating years in which they will be brought on

Table 1.1.2.3-1 Summary of potential pipe buoyancy conditions determined by terrain type analysis of the proposed route 1/

Applicant's Symbol	Description of Buoyant Conditions	Route North of 60° N Latitude Miles	(Percent)	Route South of 60° N Latitude Miles	(Percent)	Total Route Miles	(Percent)
B-0	No buoyant conditions	610.51	(53.23)	1,126.46	(87.54)	1,736.97	(71.37)
B-1	Potential buoyant conditions in route segment	225.25	(19.64)	81.06	(6.3)	306.31	(12.59)
B-2	Potential buoyant conditions in part of segment	268.70	(23.45)	57.34	(4.46)	326.24	(13.41)
	River crossings	42.21	(3.68)	21.98	(1.71)	64.19	(2.64)
	TOTAL	1,146.87	(100.00)	1,286.84	(100.01)	2,433.71	(100.01)

Source: CAGPL, 1974, 8.a.3, alignment sheets.

1/ Alignment changes near Fort Simpson (CAGPL, 1975, 8.6.3) proposed subsequent to this tabulation increase total system mileage by approximately 1 mile (0.04 percent) and introduce changes in pipe buoyancy conditions amounting to approximately 6 miles (0.25 percent).

Table 1.1.2.3-2 Summary of erosion control measures for the proposed route determined by terrain type analysis 1/

<table>
<tr><th rowspan="2">Applicant's Symbol</th><th rowspan="2">Description of terrain</th><th rowspan="2">Erosion Control Countermeasure</th><th colspan="2">Route north of 60° N Latitude</th><th colspan="2">Route south of 60° N Latitude</th><th colspan="2">Total route</th></tr>
<tr><th>Miles</th><th>(Percent)</th><th>Miles</th><th>(Percent)</th><th>Miles</th><th>(Percent)</th></tr>
<tr><td>EC-1A</td><td>Average slope along segment less than 3°; erodible soil; control measures required in low areas only.</td><td>Backfill mound breaks: spacing 50 feet</td><td>0.27</td><td>(0.02)</td><td>--</td><td>--</td><td>0.27</td><td>(0.01)</td></tr>
<tr><td>EC-1B</td><td>Average slope along segment less than 3°; erodible soil; control measures required in low areas only.</td><td>Backfill mound breaks: spacing 100 feet</td><td>69.95</td><td>(6.10)</td><td>--</td><td>--</td><td>69.95</td><td>(2.87)</td></tr>
<tr><td>EC-1C</td><td>Average slope along segment less than 3°; erodible soil; control measures required in low areas only.</td><td>Backfill mound breaks: spacing 200 feet</td><td>604.83</td><td>(52.74)</td><td>37.12</td><td>(2.88)</td><td>641.95</td><td>(26.38)</td></tr>
<tr><td>EC-1D</td><td>Average slope along segment less than 3°; erodible soil; control measures required in low areas only.</td><td>Backfill mound breaks: spacing 500 feet</td><td>292.96</td><td>(25.54)</td><td>110.48</td><td>(8.59)</td><td>403.44</td><td>(16.58)</td></tr>
<tr><td>EC-2B</td><td>Average slope along segment greater than 3°; erodible soil; close spaced control measures required.</td><td>Backfill mound breaks: spacing 100 feet</td><td>5.55</td><td>(0.48)</td><td>--</td><td>--</td><td>5.55</td><td>(0.23)</td></tr>
<tr><td>EC-2C</td><td>Average slope along segment greater than 3°; erodible soil; close spaced control measures required.</td><td>Backfill mound breaks: spacing 200 feet</td><td>87.82</td><td>(7.66)</td><td>--</td><td>--</td><td>87.82</td><td>(3.61)</td></tr>
<tr><td>EC-2D</td><td>Average slope along segment greater than 3°; erodible soil; close spaced control measures required.</td><td>Backfill mound breaks: spacing 500 feet</td><td>28.3</td><td>(2.47)</td><td>0.27</td><td>(0.02)</td><td>28.57</td><td>(1.17)</td></tr>
<tr><td>EC-4D</td><td>Average slope along segment greater than 3°; nonerodible soil; control measures required in low areas only.</td><td>Backfill mound breaks: spacing 500 feet</td><td>1.45</td><td>(0.13)</td><td>--</td><td>--</td><td>1.45</td><td>(0.06)</td></tr>
</table>

Table 1.1.2.3-2 (Continued)

Applicant's Symbol	Description of Terrain	Erosion Control Countermeasure	Route North of 60° N Latitude Miles	(Percent)	Route South of 60° N Latitude Miles	(Percent)	Total Route Miles	(Percent)
EC-7	Steep scarps	Control measures at steep scarps	7.0	(0.61)	--	--	7.0	(0.29)
EC-8	Low-lying sensitive areas	Preserve microdrainage in low-lying sensitive areas	102.97	(8.98)	2.98	(0.23)	105.95	(4.35)
EC-8D	Low-lying sensitive areas	Backfill mound breaks: spacing 500 feet	1.23	(0.11)	--	--	1.23	(0.05)
--		River crossings	42.21	(3.68)	21.98	(1.71)	64.19	(2.64)
--		Control measures not required	--	--	1,114.01	(86.57)	1,114.01	(45.78)
SUBTOTAL			1,244.54	(108.52)	1,286.84	(100.00)	2,531.38	(104.02)
	Correction for double counting of segments requiring two or more control measures		97.77	(-8.52)	--	--	-97.77	(-4.02)
TOTAL			1,146.77	(100.00)	1,286.84	(100.00)	2,433.61	(100.00)

Source: CAGPL, 1974, 8.a.3, alignment sheets.

1/ Alignment changes near Fort Simpson made subsequent to table tabulation (CAGPL, 1975, 8.6.3) increase total system length by about 1 mile (0.04 percent) and introduce insignificant changes in the distribution of erosion control measures probably amounting to less than 0.5 percent of total system mileage.

stream are shown in Table 1.1.2.3-3. Station locations are shown in Figure 1.1.2.2-1.

North of Fort Simpson, in the part of the proposed system that crosses the zones of continuous and discontinuous permafrost, compressor stations will have single 30,000-horsepower gas turbine main compressors and closed loop propane refrigeration systems powered by 17,000 horsepower gas turbines. These facilities will boost transmission pressures by approximately 350 psi and chill the gas to temperatures between 12° and 16° F. (CAGPL, 1974, 8.b.4, sec. 1-9, 1-10). The four compressor stations south of Fort Simpson comprise a transition zone between chilled and unchilled gas. The northern two stations in the transition zone will have single, 30,000-horsepower compressors, the southern two will each have two 27,500-horsepower gas turbines connected in series. There will be no provision for gas cooling in the transition zone, so temperatures will rise from approximately 24° F in the north to approximately 70° F in the south. Beyond the transition zone, compressor stations will have gas turbines connected in series to total 55,000 horsepower. The stations between the transition zone and Caroline Junction wil have direct air exchange gas coolers but there would be no need for either cooling or chilling on the delivery lines extending to Kingsgate and Monchy. Gas will reach Kingsgate at temperatures in the 70's and Monchy at just over 100° F. On the Kingsgate Delivery Line no compressor stations will be required during the first 5 operating years; eventually, single-unit 26,000-horsepower compressors may be required. On the Monchy Delivery Line, the stations west of the Trans Canada delivery point will incorporate twin 27,500-horsepower compressors; those located east of that point will be 26,000 horsepower (CAGPL, 1975, 8.b.1.1, p. 7-8).

The looping of the existing Alberta Natural Gas 106-mile-long pipeline between Kingsgate and the British Columbia-Alberta border would require expansion of compressor horsepower at two existing compressor stations located at miles 46.9 and 79.8. Two 13,500-horsepower centrifugal compressor units would be added to each station.

Compressor stations will be constructed within a fenced compound that encloses from 630,000 to 1,080,000 square feet, depending on station requirements. Figure 1.1.2.3-2 provides a generalized plan of a large compressor and refrigeration station.

Access to compressor stations during preconstruction, construction, and operation phases will be provided by airstrips, helipads, or roads. The stations will be remote-controlled by means of communication links relaying operating parameters and safety signals to the Gas Control Center near Calgary. Housing facilities will be limited to temporary sleeping quarters at the southerly locations with more complete living accommodations for visits of maintenance personnel at northerly, more remote locations. Buildings for main functions, equipment and personnel will be constructed of steel, heated and insulated as required, and built on piling foundations in thaw-susceptible soils in permafrost areas. All stations will have emergency electrical generators capable of maintaining essential services, and stations not near commercial electrical power sources will have natural gas fueled turbines connected to electrical generating units.

Although the principal purpose of the compressor and refrigeration stations is to force gas through the pipeline, the design of the proposed system requires that they serve a variety of additional functions during the preconstruction, construction, operation, and maintenance phases of the proposed project. In many ways the stations are crucial system nodes. Figure 1.1.2.3-3 generalizes the variety of components and functions that

Table 1.1.2.3-3 Number of compressor stations required by operating year

	Operating year						
	1	2	3	4	5	Future	Total
Prudhoe Bay Supply Line	-	2	-	-	-	4	6
Richards Island Supply Line	-	-	-	-	-	2	2
Main Line	9	7	8	7	-	-	31
Kingsgate Delivery Line	-	-	-	-	-	4	4
Monchy Delivery Line	-	2	-	1	-	4	7
Total	9	11	8	8	0	14	50

Source: CAGPL, 1974, 13.a.2.2, drawing 4-0234-1004

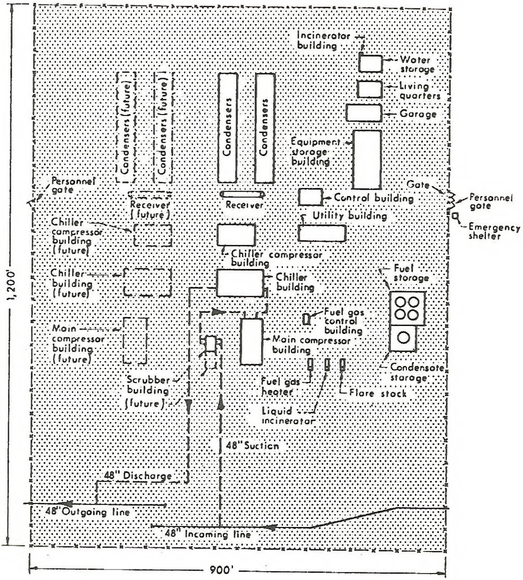


Figure 1.1.2.3-2 Typical compressor station layout for 30,000-horsepower compressor and 17,000-horsepower refrigeration plant

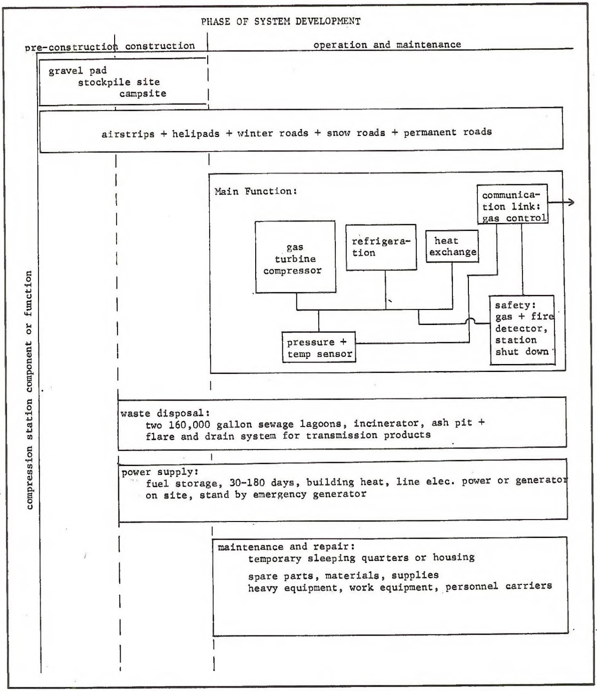

PHASE OF SYSTEM DEVELOPMENT
pre-construction
construction
operation and maintenance
compression station component or function
gravel pad
stockpile site
campsite
airstrips + helipads + winter roads + snow roads + permanent roads
Main Function:
communication link: gas control
gas turbine compressor
refrigeration
heat exchange
safety: gas + fire detector, station shut down
pressure + temp sensor
waste disposal: two 160,000 gallon sewage lagoons, incinerator, ash pit + flare and drain system for transmission products
power supply: fuel storage, 30-180 days, building heat, line elec. power or generator on site, stand by emergency generator
maintenance and repair: temporary sleeping quarters or housing
spare parts, materials, supplies
heavy equipment, work equipment, personnel carriers

Figure 1.1.2.3-3 Diagrammatic representation of compressor station functions and components as they would evolve during development of the proposed system

will be in operation at station locations during different phases in the development of the system.

In the preconstruction phase, after laying the gravel pad and developing transportation access by road or air, a compressor station location will function mainly as a stockpile site for the marshaling of pipe, equipment and materials needed in construction of the compressor station and the adjacent pipeline segments. In the construction phase, the station location will be used as a campsite, supply depot, and materiel and manpower portal for adjacent pipeline spreads; it will also be the primary site for waste disposal. Transportation, access, and waste disposal functions will continue into the operation and maintenance phase when the compressor station will be pressurizing and cooling gas, monitoring operating and safety systems for communication to the Gas Control Center, and serving as the fundamental control point for pipeline surveillance, maintenance, and repair.

Valves

Block valves that will completely shut off gas transmission will be located at each compressor station and at sites approximately midway between compressor stations (CAGPL, 1974, 14.d.5.2.1, p. 5). The valves will be of the "full opening through conduit type" (CAGPL, 1974, 8.b.1.4.2, p. 4) and will be closed or opened by gas-hydraulic or motor-driven valve operators. Blowdown valves and stacks, braced and anchored to resist the forces exerted during blowdown, will be located at each block valve; operation of two blowdown assemblies will vent a section of the proposed pipeline within an hour (CAGPL, 1974, 14.d.5.2.1, p. 5).

Block valve operators and some associated components will be located in buildings constructed above the pipe centerline (CAGPL, 1974, 8.b.3, sheet B-1), but details of the housing, configuration, operation, and construction of block valves have not been provided by the Applicant.

Gas Measuring Stations

Instruments to measure the quantity and quality of gas passing through the pipeline will be installed at compressor stations, at points on the supply and delivery laterals, and on the Main Line. Data, recorded at the site and telemetered to the Gas Control Center, will be used in computer programs to optimize transmission and execute receipt, transmission, use and delivery accountings.

Major measurement stations will be independent of compressor stations and located (1) south of Phillips Bay on the Prudhoe Bay Supply Line, (2) north of the Parsons Lake Lateral on the Richards Island Supply Line, (3) at the Alberta-Northwest Territories border, (4) near Valleyview in central Alberta on the Main Line, (5) approximately on the British Columbia-Alberta border north of Fernie on the Kingsgate Delivery Line, (6) at Kingsgate, (7) near the Alberta-Saskatchewan border on the Monchy Delivery Line, and (8) at Monchy. These metering stations will be constructed within a fenced area not more than 250,000 square feet. Within the compound will be a meter building approximately 75 by 150 feet in size and a smaller instrument building. At the northern locations on the supply lines, buildings will be constructed on arctic piling foundations and the compound will enclose a gravel pad. Each measurement station will have two meter runs in order to provide for equipment failure, maintenance, and repair without interrupting transmission.

Information on measurement facilities at compressor stations has not been provided by the Applicant.

Communications

Communication systems will be required during both the construction and operation phases of the proposed pipeline. Communication requirements during construction will be to: (1) link construction camps to existing public telephone networks; (2) provide mobile radio communication between construction camps, working spreads, engineers, and such elements of the support system as the barge, aircraft, and truck fleets; and (3) facilitate data transmission. These requirements will be met using existing public communication networks, additions to those networks provided by the Applicant, or portions of the permanent, pipeline-dedicated communications system (CAGPL, 1974, 13.a.2.3.3, p. 10). The portable radio network used during construction will be similar to conventional, fixed microwave systems but will have the capability of being put into service on short notice. It will operate on 150- and 900-MHz bands and be powered by small, engine-driven generators. Light weight, scaffold-type antennas will be used (CAGPL, 1974, 8.b.7.5, p. 9).

The permanent communications system that will be required during operation of the proposed pipeline will handle both voice and data traffic. The basic purposes will be to link the Gas Control Center at Calgary with the metering and compressor stations in order to remotely control throughput and to link the operating District Offices to Gas Control, compressor stations and other facilities in order to monitor performance and devise maintenance strategy. The major elements of the operating communications system will be: (1) a "backbone" microwave radio system paralleling the pipeline with multiplex equipment for voice and data circuits; (2) a company telephone system; and (3) a mobile radio system. Only the microwave system will require extensive construction.

More than 80 microwave communication sites will be located along the proposed pipeline. The sites will be at each compressor and metering station and at line-of-sight points approximately midway between stations. Communication sites will encompass 8 to 10 acres on which a 205-foot tower supported by three guy cables anchored at points 142 feet from the base of the tower will be erected. Communication sites south of 60° N latitude will have gravel pads around the base of the tower occupying an area of between 2,900 and 3,800 square feet (CAGPL, 1974, 8.b.3, sheet E-1). At compressor stations and other locations with line electrical power a single communications equipment building will be located on the pad, and the pad will be connected by a gravel road to the station or access road. Each site without line power will have a buried fuel tank and a second building containing electrical generating equipment. North of 60° N. latitude the communications sites will have a 5,600-square-foot pad connected by a path to a nearby, 4,900-square-foot helicopter pad. The communication equipment and generator buildings will be located on the pad near an aboveground fuel tank.

Roads

Movement of materiel to stockpile sites will be by rail and barge transportation or by trucks using existing or planned government roads, supplemented where necessary by new roads built by the Applicant. The transportation of materials, equipment, and supplies from stockpiles to construction sites will also be by truck and will require building many miles of permanent and temporary roads.

The major highways of western Canada are shown in Figure 1.1.2.3-4. Southward from a point 50 miles north of Peace River the existing highway network provides good access to the proposed route. Access to the proposed right-of-way between Peace River and Fort Simpson, however, will require extensive construction of access roads from Highway 58 between Peace River and Hay River and from the highway connecting Hay River and Fort Simpson. North of Fort Simpson the proposed right-of-way closely follows the Mackenzie River and the proposed Mackenzie Highway and only short access roads will have to be constructed to reach either wharves on the river or the highway should it be built prior to the pipeline (present scheduling indicates that this will not be the case). Access to the segment of the proposed pipeline between Fort McPherson and the Alaska border will be from the Dempster Highway and will require extensive access road construction.

Three major types of roads will be built: (1) temporary access snow or winter roads, (2) winter trails, and (3) permanent gravel roads. Table 1.1.2.3-4 provides the mileages of each type called for by the design in each construction spread. Construction of the entire pipeline system entails building about 255 miles of temporary snow or winter roads, 230 miles of winter trails, and 67 miles of permanent gravel roads.

Temporary snow roads would be used extensively--especially north of 65° N. latitude--because winter construction is planned for much of the pipeline system. They will be used " ... in all areas of sensitive permafrost to provide access to rights-of-way, borrow pits, stockpile sites and wharves, and to provide a traffic lane for ... the working side of the pipeline right-of-way" (CAGPL, 1974, 13.a.6.4.1,p. 31). Snow roads to provide access to the right-of-way and related facilities will be of sufficient thickness and density to withstand 35,000 passes of wheeled, heavy vehicle traffic (CAGPL, 1974, 13.a.6.4.1, p. 31). These roads will be approximately 32 feet wide and will accommodate two traffic lanes. The snow roads comprising the working side of the pipeline right-of-way will be less durable because they will only be used by slow moving construction equipment. The roads will be built by mounding, packing, and grading snow accumulated along a cleared right-of-way after frost has penetrated the ground. If there is not enough snow, more will be obtained by catching it against specially placed fences or quarrying and transporting it to the roadway. In some instances, increased strength and durability will be obtained by forming an ice surface on the roadway.

Temporary winter roads in conventional (non-permafrost) winter construction areas will be built by merely clearing, grading, and waiting for the frost to penetrate. Vehicles will travel on the frozen ground surface.

Winter trails will be used by tracked vehicles and equipment and require no construction except route marking and clearing.

Permanent gravel roads will be constructed at very heavily traveled nodes in the transportation network, and at places where frequent traffic for maintenance purposes will be envisioned. The roads will occupy a 120-foot right-of-way, be designed for two-way traffic at 30 mph, and have load capacities commensurate with those of any existing highways they will join. Embankment thickness will be a minimum of 2 to 3 feet over non-frost-susceptible soil, but greater thicknesses will be used in thaw-susceptible soils. Roads in permafrost areas will employ a variety of arctic engineering practices, including routing away from streams, vegetation buffer strips, closer spacing and erosion control armoring of culverts, side ditching by compaction instead of excavation, route location to avoid cut grading, and cross-ditching (CAGPL, 1974, 8.b.1.3, p. 63-64).

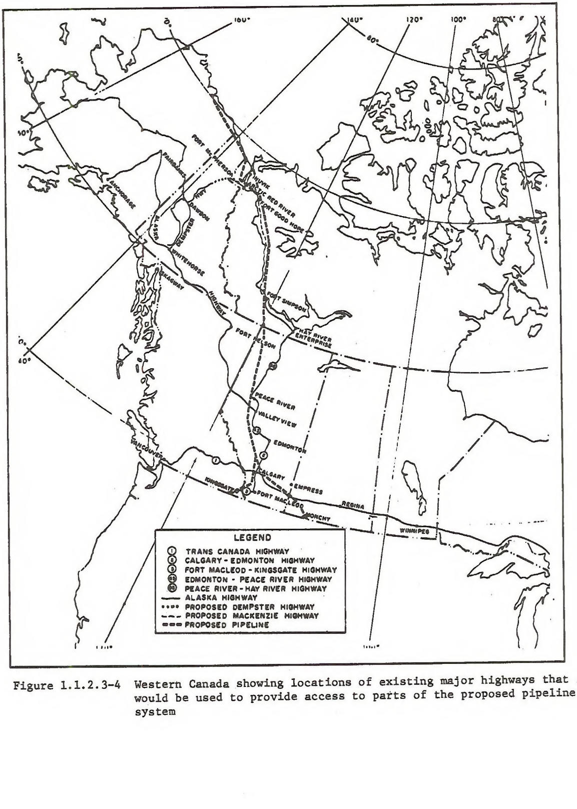


Figure 1.1.2.3-4 Western Canada showing locations of existing major highways that would be used to provide access to parts of the proposed pipeline system

Table 1.1.2.3-4 Types of roads by line segment and construction spread 1/

Line segment/spread	Permanent gravel road	Snow or temporary winter road	Winter trail
Richards Island Supply Line			
A	1.5	15.5	16.5
Prudhoe Bay Supply Line			
C	--	7.3	10.0
E	--	14.6	2.0
F	2.3	8.5	3.0
G	--	5.5	7.0
H	2.0	15.0	1.5
Subtotal	4.3	50.9	23.5
Main Line			
B	11.0	55.0	25.0
C	2.0	25.0	40.0
D	7.0	25.5	12.0
E	21.5	16.0	21.5
F	--	54.5	20.0
G	20.0	10.5	52.0
H	--	--	4.5
I	--	1.0	3.0
Subtotal	61.5	187.5	178.0
Kingsgate Delivery Line			
G	--	--	4.5
H	--	--	--

Table continues)

Table 1.1.2.3-4 (Continued)

	Permanent gravel road	Snow or temporary winter road	Winter trail
Subtotal ---------	--	--	4.5
Monchy Delivery Line			
E --------------------	--	1.5	4.0
F --------------------	--	--	3.0
Subtotal ---------	--	1.5	7.0
Grand Total--	67.3	255.4	229.5

---

[1] The approximate locations of construction spreads A through I are shown in Figure 1.1.2.5-1.

Airstrips and Helicopter Pads

Airstrips will be required during the construction and operation of the proposed pipeline system. During construction, primary uses of airstrips will be in transporting men and materiel; during operation, airstrips will facilitate surveillance of the pipeline and the movement of personnel and supplies needed in maintenance.

At least 28 airstrips will be in use by the pipeline system, including suitable existing airstrips at Inuvik, Norman Wells, Fort Simpson and Hay River. The Applicant will also improve and use existing airstrips at Fort Norman, Wrigley, and Fort Good Hope. Twenty-one airstrips equipped for Instrument Flight Rule landings will be constructed in the course of development of the pipeline; 5 of these will be 6,000 feet long, suitable for heavy transport aircraft, and 16 will be 2,400 feet long, suitable only for short-take-off-and-landing aircraft. The longer airstrips will be 500 feet wide with a traveled area approximately 150 feet wide; the shorter ones will be 300 feet wide with a traveled area approximately 150 feet wide.

The airstrips will be constructed of gravel and will have a building to house a flight office, communication center, airstrip beacon, emergency generator, vehicle, and emergency accommodations for 5 persons. The thickness of the gravel pad in permafrost areas depends on the engineering properties of the foundation soil. In thaw-susceptible soil the pad will be thick enough to maintain the 32° F isotherm within the gravel (CAGPL, 1974,--13.a., 8.b.1.4.5, p. 21); in soils lacking thaw problems, pad thickness will be determined only by the requirement for a structurally competent surface.

About 170 helicopter pads equipped with windsocks, floodlights, and non-glare indicating lights will be built at such locations as remote communications towers, valves, and metering stations. The dimensions of the pads will be approximately 60 by 60 feet.

Wharves and Stockpiles

During the first 2 years of construction of the proposed pipeline system, materiel amounting to more than an estimated 2 million tons will have to be moved from the railhead-staging area at Hay River to stockpile sites along the northern 850 miles of the route (CAGPL, 1974, 13.a.3, table p. 20). These supplies will be moved by a waterway transportation system consisting of 5 tugboats, 48 barges and at least 19 wharves (CAGPL, 1975, 13.a., drawing 4-023-1004). Proposed wharf sites have been selected and are shown in Figure 1.1.2.2-1. Two wharves with stockpiles will be located on the shore of Mackenzie Bay; the remaining wharves will be situated on the Mackenzie River.

A general appreciation of the size and type of facilities to be constructed can be gained from the preliminary design (CAGPL, 1974, responses) for a wharf and stockpile on the Mackenzie River west of compressor station M-05 (figure 1.1.2.2-1). A wharf and a fuel barge mooring will be built along the river bank; both will extend sufficiently far from the bank to reach river depths at low water adequate for barges with a draft of 5 feet. The wharf will be approximately 100 feet long and 60 feet wide; its river face will be formed of steel sheet piling to provide a retaining wall for a gravel-surfaced fill prism. The fuel barge mooring will consist of two caissons sunk into the river bed approximately 250 feet apart. Piping through which the fuel will be pumped to the storage area will be onshore at the mooring.

Landward of the wharf and mooring, a variety of facilities will be built in a cleared area of approximately 25 acres. Installations planned include: 1) a diked compound approximately 500 by 1,200 feet for storage, in fabric tanks, of up to 2,500,000 imperial gallons of gasoline, aviation fuel, heating oil, and diesel fuel; 2) a storage area for approximately 46 miles of pipe, occupying an area approximately 450 by 650 feet; 3) a storage area having dimensions of 150 by 250 feet for approximately 100,000 imperial gallons of propane; 4) six storage buildings in an area approximately 150 by 500 feet; 5) a camp for 100 workers built in an area 250 by 250 feet; 6) a utilities area containing power, water purification, and sewage disposal plants; and 7) at some distance, a magazine for storage of approximately 500 tons of explosives. These facilities will be linked by gravel roads.

Figure 1.1.2.2-1 also shows locations of stockpile sites to be developed during the course of the proposed project. Stockpiles will be built at future compressor station sites and at other sites specifically constructed for material-handling purposes (CAGPL, 1974, 14.d.5.3.1, p. 8). Presumably they will be similar in size and facilities to the storage areas that will be developed at wharves.

Borrow Pits

Construction of the proposed pipeline system will require large quantities of gravel for the fabrication of roads, airstrips, helipads, compressor and measuring stations, and other facilities related to construction and operation. The quantities of gravel required and the uses to which it will be put are shown in Table 1.1.2.3-5. Much more gravel will be used in pipeline segments north of 60° N. latitude than in the southern segments. Data on locations and dimensions of borrow pits are presented in Tables 3.1.2.2-15 through -18. Conventional methods and equipment will be used to excavate gravel from borrow pits located as close as possible to the construction. Approximately 108 borrow pits will be required; most of the pits will be located along the supply laterals and the northern part of the proposed Main Line. Borrow will generally be excavated and used during the winter construction season so the pits will be linked to the construction sites by snow roads or temporary winter roads (CAGPL, 1974, 13.a.6.4.3, p. 33).

The millions of cubic yards of borrow required during the 4 years of construction of the proposed pipeline system are listed below (source: CAGPL, 1974, 13.a.5.4, p. 23).

	Construction year				
	1	2	3	4	Total
Winter construction season	6.5	7.9	4.2	0.3	18.9
Summer construction season	2.8	3.5	1.8	-	8.1
Total	9.3	11.4	6.0	0.3	27.0

Approximately 27 million cubic yards of borrow material will be used. Information has not been presented on the additional borrow requirements that will result from the need for select bedding and ditch fill or from the maintenance operations of the proposed pipeline and its related structures.

After borrow extraction, pits may be used as "preferred burial sites" for the disposal of stumps, brush, and non-combustible waste collected from the site and from adjacent segments of road and pipeline rights-of-way. Waste materials placed in abandoned borrow pits will be covered with burden stripped from the pit (CAGPL, 1974, 13.a.6.8, p. 58).

Table 1.1.2.3-5 Gravel quantities and uses for segments of the proposed pipeline system

	Prudhoe Bay Supply Line	Richards I. Supply Line & Parsons Lake Lateral	Main Line North of 60° N Latitude	Main Line South of 60° N Latitude	Monchy Delivery Line	Kingsgate Delivery Line	Total
Compressor Station							
Pad	1,950	600	5,890	2,000	70	50	10,560
Airstrip	2,940	210	3,740	280	-	-	7,170
Road	243	75	2,850	334	-	-	3,502
Communications Tower	16	6	30	18	8	7	85
River Delivery Site							
Camp & Stockpile Pad	967	290	2,189	-	-	-	3,446
Road	133	-	-	-	-	-	133
Helipad	-	1	-	-	-	-	1
Meter Station	25	48	-	-	-	-	73
Stockpile Pad	145	258	219	-	-	-	622
Camp & Stockpile Site	983	-	-	-	-	-	1,015
Airstrip	160	-	-	32	-	-	160
Road	100	-	-	-	-	-	100
Access Road	50	-	-	-	-	-	50
Operations & Maintenance Pad	-	104	156	12	-	-	272
Total	7,712	1,592	15,074	2,676	78	57	27,189
Cubic yards per mile in pipeline segments	26.0	10.1	22.0	4.4	0.2	0.2	

Restoration of abandoned dry borrow pits consists of bulldozing and grading to subdue relief, and fertilizing and seeding to promote revegetation. Pits filled with water will be graded and seeded along the banks, thus " ... producing a naturally stable lake" (CAGPL, 1974, 13.a.6.8, p. 58).

Construction Camps

Manpower requirements for construction of the proposed pipeline system vary from 1,500 to 7,500, depending on the season and phase of the project (CAGPL, 1974, 13.a.6, p. 24). Most workers will be housed in temporary camps that will be moved at intervals as the work progresses and removed completely upon completion of the project. The Applicant describes construction camps at three scales: 10 to 50 persons, 50 to 200, and 500 to 800 (CAGPL, 1974, 13.a.6.4.5, pp. 35-36). These descriptions are paraphrased in the following paragraphs.

Pre-construction activities such as surveying, materials testing, environmental research, initial equipment and materials reception, and small-scale clearing would be conducted from camps designed for 10 to 50 workers. The camps will be at one location for short periods of time, generally ranging from a few days to a few months, and will be moved by all-terrain vehicles, helicopters, barges or snow road sleds. Completely self-contained waste treatment and disposal facilities will be part of each camp.

Camps serving from 50 to 200 workers will be used in site preparation, materials receiving, and compressor station construction. The camps will be on site for periods of up to a year and be served by the river or coastal barge system, permanent access roads, snow or winter roads, or helicopters or fixed wing aircraft. The camps will have modular bunk room units, workshop and recreation buildings, and food preparation, serving and eating facilities. Waste treatment and disposal systems and water supply will be developed on or near the site.

Camps accommodating 500 to 800 workers will be required for the major construction activities along the working spreads and at principal staging areas. They will be located either at future compressor stations or at large unloading sites. The design for a typical 800-man camp (CAGPL, 1974, 13.a.6.4.5, drawing 4-0600-2003) includes 112-man lodging buildings with heating, washing and laundry facilities; 60 by 100-foot mess halls; and recreation, medical, workshop, warehouse, fire station, and power generating buildings. The number, location, construction year used, and duration of occupancy for the major pipeline camps are listed in table 1.1.2.3-6.

Construction of large and intermediate sized camps will require unspecified amounts of grading and site preparation, foundation work, and road and pad building.

Sewage treatment at construction camps generally will consist of "secondary treatment prior to discharge to the environment" (CAGPL, 1974, 8.b.1.4.6, p. 25). Either diked or excavated sewage lagoons or package treatment plants will be involved. The sewage lagoons will retain waste water for about a year and hold 160,000 Imperial gallons; they may be constructed so as to use existing small ponds advantageously (CAGPL, 1974, 8.b.1.4.6, p. 25). Package treatment plants will be biological or physico-chemical in operation. Aeration or "bio-disc" circulation will be employed, accompanied by periodic withdrawal and incineration of sludge. Residue will be buried in ash pits.

Table 1.1.2.3-6 Location, time, and duration of occupancy of pipeline construction camps

	Construction Spread	Route Milepost	Construction Year .1...2...3...4...5..	Compressor Station, wharf* or townsite
Richards Island Supply Line	A	25	XXX	RMP-1044*
		39.2	X	M-01
		94.9	XXXX	M-02
Prudhoe Bay Supply Line	C	216	XXX	Komakuk Beach*
	E	270	X	CA-06
		300	XXX	Shingle Point*
	F	360	XXX	CA-08
	G	395	XXX	RMP-990*
		408	X	CA-09
	H	460	X	RMP-902*
Main Line, North of 60° N Latitude	B	143.3	X	M-03
		176	XXX	M-04
		220	X	M-05
		264	XXX	M-06
	C	290	XXX	Ft. Good Hope
		310	X	M-07
		357	XXXX	M-08
		400	XX	M-09
	D	445	X	M-10
		490	XXX	M-11
		534	X	M-12
		580	XXX	ME-13
	E	620	XXX	ME-14
		675	XXX	ME-15
		720	X	ME-16
	F	775	X	ME-17
		810	XXXX	ME-18
Main Line, South of 60° N Latitude		860	XX	ME-19

Table 1.1.2.3-6 (Continued)

Construction Spread	Route Milepost	Construction Year	Compressor Station, wharf* or townsite
		`.1...2...3...4...5..`	
G	900	`       XX`	M-20
	940	`         X`	M-21
	980	`         XXXX`	M-22
	1020	`             X`	M-23
H	1063	`             X`	M-24
	1090	`          XXX`	Brownvale
	1150	`         X`	M-26
	1180	`      XXX`	Valleyview

Cost of Facilities

Constructing the proposed natural gas transportation system is estimated to cost 5.5 billion Canadian dollars[1] at 1974 cost levels; the estimate increases to 7.0 billion Canadian dollars if allowance is made for cost escalation during the construction period (CAGPL, 1974, 10, p. 1). Of the estimated cost, 25 percent will be provided by equity funds, 75 percent by various types of debt instruments (CAGPL, 1974, 15, p. 2).

The costs that would be incurred by Alberta Natural Gas in looping its existing 36-inch pipeline between Kingsgate and the British Columbia-Alberta border depend on the planned delivery rate. As was the case in pipeline design (see section 1.1.2.3, Pipeline), estimates have been presented at three levels of gas transmission: 1) expenditures of $20.4 million (Canadian dollars) would be required to transmit an additional 200 MMcf/d (million cubic feet per day); 2) $40.7 million would be required to transmit an additional 600 MMcf/d; and 3) $66.1 million would be required to transmit an additional 1,200 MMcf/d.

1.1.2.4 Land Requirements

Construction of the proposed pipeline system in Canada requires approximately 67 square miles of land. Approximately 80 percent will be devoted to the 120-foot pipeline right-of-way for the 2,435-mile system. The remaining 20 percent of the land needed will be used for the construction of related facilities (CAGPL, 1974, 13.a.2.2).

The land requirements of the proposed project are summarized by pipeline segment and proposed use in Table 1.1.2.4-1. The pipeline right-of-way requires 35,132 acres. Land for airfields totals 2,780 acres, mostly in parcels ranging from 175 to 300 acres. Compressor station requirements, varying from 29 to 43 acres each, total 1,808 acres. Roads will be built over 1,011 acres. Land requirements for communication towers, wharves, and miscellaneous uses amount to less than 1,000 acres.

1.1.2.5 Schedule

Construction of the proposed natural gas transportation system will continue into the seventh year after the start of the project (CAGPL, 1974, 13.a.2.3.2, Figure 1). The first and second construction years will be occupied mainly with surveying, materiel acquisition and stockpiling, site preparation, and logistic development. Pipeline construction will begin late in the second year and continue into the fifth. Station construction will begin in the fall of the third year and continue until early in the seventh.

The original plans for the proposed pipeline project called for the first construction year to be 1975 (CAGPL, 1974, 13.a.2.1, p. 5). In November 1974, however, Canadian Arctic Gas Pipeline Limited changed the proposed construction schedule by 1 year (CAGPL, 1974, 15, unpaged supplement); the first construction year will be 1976.

Pipeline

The construction schedule for the buried pipeline is a 5-year timetable that will bring first deliveries of Mackenzie Delta gas in the summer of the

---

[1] For procurement in the United States, an exchange rate of $1 Canadian = $1.02 U.S. was assumed (CAGPL, 1974, 10, p. 2)

Table 1.1.2.4-1 Land requirements (acres) for proposed pipeline system 1/

Pipeline Segment	Right-Of-Way	Communication Towers	Compressor Stations	Airfields	Roads	Borrow Pits	Wharves	Misc.2/	Total
Prudhoe Bay Supply Line	4,409	33	219	730	132	433	122	112	6,190
Richards Island Supply Line	1,935	16	71	100	22	177	--	75	2,396
Main Line--Travaillant Lake to 60° N Latitude	10,018	83	645	1,600	825	623	230	51	14,075
Main Line--60° N Latitude to Caroline Junction	8,942	83	552	350	32	200	--	8	10,167
Monchy Delivery Line	5,739	44	204	--	--	--	--	--	5,987
Kingsgate Delivery Line	4,089	39	117	--	--	--	--	--	4,245
TOTALS	35,132	298	1,808	2,780	1,011	1,433	352	246	43,060

1/ After CAGPL, 1974, 13.a.2.2 and later submittals.
2/ Camps, stockpiles, meter stations, highway junctions, helipads, operations, and maintenance bases.

fourth construction year and first deliveries of Prudhoe Bay gas in the summer of the fifth. The main elements of the proposed construction plan are diagrammatically shown in Figure 1.1.2.5-1.

The construction plan divides the proposed pipeline route into segments which average about 60 miles on the Prudhoe Bay Supply Line and about 160 miles along the rest of the pipeline. The 19 route segments will be completed using 9 construction crews (A through I in Figure 1.1.2.5-1) whose movement from one segment to another will be phased according to the preferable construction season for each segment. North of Caroline Junction, winter construction will be used.

Construction of the Richards Island Supply Line and the part of the Main Line north of Fort Simpson will be undertaken during the winters of construction years 2-3 and 3-4. Materiel and heavy equipment will be left on the site during the intervening summer of the third year (CAGPL, 1974, 13.a.2.3.1, p. 8). The construction segments from Fort Simpson to Caroline Junction require the work of five construction crews during the winters of construction years 2-3 and 3-4. During the summer of the third year, however, these crews will move south to build the delivery lines. The Prudhoe Bay Supply Line will be started and completed during the winter of construction year 4-5.

Stations

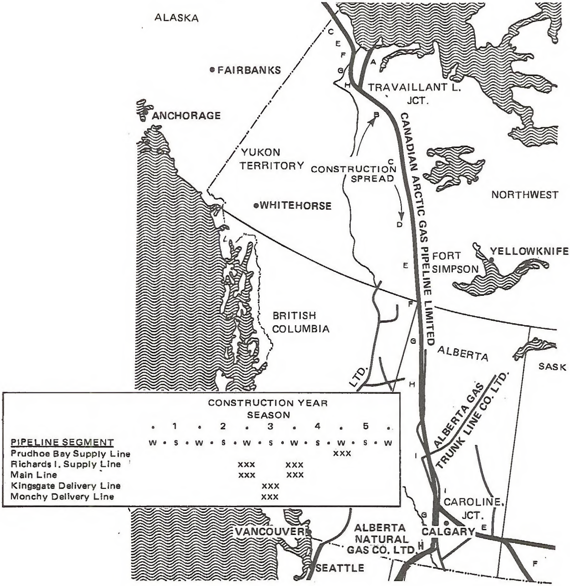
The design of the proposed pipeline system incorporates 50 compressor and 8 metering stations. Construction will be completed on 36 compressor stations during the first 6 years of the project. Fourteen additional compressor stations called for in the design will be built at a future, unspecified time.

The locations of metering and compressor stations are shown in Figure 1.1.2.2-1 and the operating year in which they will come on stream is listed in Table 1.1.2.3-3. The Applicant's proposed station construction schedule is reproduced as Figure 1.1.2.5-2.

More time will be required to construct compressor stations located on the northern part of the proposed pipeline because of the refrigeration plants, more extensive site preparations, and more complicated logistics. North of Main Line station ME-15 near Fort Simpson, 10 to 15 months centered around winter construction seasons will be needed to build the stations after up to 6 months site preparation and equipment move-in time. Between Fort Simpson and Caroline Junction, station construction will require 7 to 8 months and about 3 months preparation and move-in. Stations on the delivery lines will take 3 to 4 months to build after about 6 weeks of preparatory activities.

Gas metering stations require 3 to 4 months of construction time after approximately 6 weeks of site preparation.

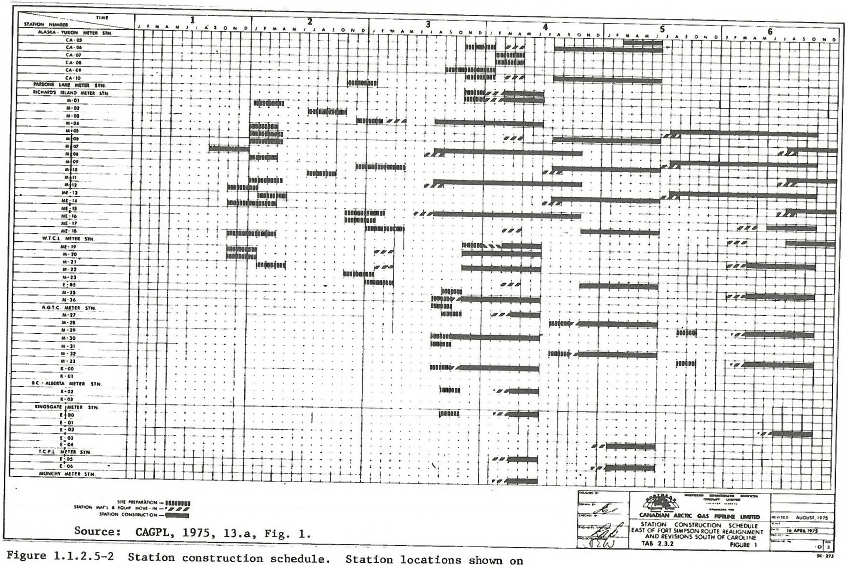
Activities at compressor and meter station sites will begin in the fall of the first year of the project (Figure 1.1.2.5-2) and continue intermittently through the winter between the second and third construction years. Compressor station construction, however, will not commence until the fall of the third construction year. It will continue at different station locations at about the same general level of intensity through the fourth, fifth, and sixth years. The last three stations will probably be completed in the spring of the seventh year of the project.



CONSTRUCTION YEAR
SEASON

PIPELINE SEGMENT		1		2		3		4		5	
	W	S	W	S	W	S	W	S	W	S	W
Prudhoe Bay Supply Line									XXX		
Richards I. Supply Line					XXX		XXX				
Main Line					XXX		XXX				
Kingsgate Delivery Line						XXX					
Monchy Delivery Line						XXX					

Figure 1.1.2.5-1 Construction spreads and schedule for proposed pipeline construction



Source: CAGPL, 1975, 13.a, Fig. 1.

Figure 1.1.2.5-2 Station construction schedule. Station locations shown on Figure 1.1.2.2-1

Other Facilities

The proposed construction schedule for the pipeline and compressor stations will be the primary determinant in the construction schedule for related facilities such as access routes, communications systems, and operational bases.

Civil construction such as roads, airfields, and station pads will require a time interval of up to 10 months sometime prior to actual construction of pipeline or compressor stations. On the Prudhoe Bay Supply Line, this will be undertaken during the winter of construction year 3-4; elsewhere it will be accomplished during the last half of the first year or the start of the second year.

Activities preparatory to pipeline installation such as materiel reception, double jointing, clearing, rock excavation and mobilization will be conducted in the 6 months prior to pipe laying. For most of the proposed route, these activities will take place during the summer and fall of year 2. Along the route of the Prudhoe Bay Supply Line the preparatory work would occur during the winter of construction year 3-4.

Submerged river crossings of the Mackenzie, Great Bear, South Saskatchewan, Peace, Smoky, Elk, and Kootenay Rivers will require about 2 months each during the early fall of year 3. River crossing preconstruction activities such as approach preparation, prefabrication, and ditch excavation will take place during the preceding 10 months. Crossings of the Mackenzie and Peel along the Prudhoe Bay Supply Line will be finished in the fall of year 4.

The permanent communication system will be completed and in operation before July of the fourth construction year. Operations and maintenance facilities will be required by spring of the third year at some Main Line compressor stations, by July of the fourth year on all of the pipeline except the Prudhoe Bay Supply Line, and by spring of the fifth year on the Prudhoe Bay Supply Line.

1.1.2.6 Construction Procedures

The major facilities to be constructed as the proposed project are the buried pipeline, compressor stations, airfields, roads, communication towers and wharves. The design of the facilities is described in section 1.1.2.3 (Facilities). This section outlines the construction procedures to be used in building these components of the proposed natural gas transportation system. The description is based exclusively on information supplied by Canadian Arctic Gas Pipeline Limited (CAGPL, 1974, especially 13.a.6, p. 26-59).

Also considered under "Construction Procedures" are the human resources--workforces and skill levels--that will be employed during the building of the proposed pipeline system. As was the case for construction procedures, the description of the human resources required is based exclusively on data supplied by the Applicant (CAGPL, 1974, 13.a.5.1, p. 22).

Construction Zones

Although most of the procedures to be employed are considered standard pipeline construction practices, some variations in scheduling procedure will be used because the proposed route traverses landscapes dominated by arctic climate and wildlife, and underlain by perennially frozen soil. The variations in timing and procedures to be used are prescribed by dividing the route into three zones: (1) summer construction, (2) conventional winter construction, and (3) arctic winter construction.

Summer Construction Zone

The delivery lines extending from Caroline Junction to Kingsgate, British Columbia, and Monchy, Saskatchewan (Figure 1.1.2.2-1) will be installed during the summer construction season (Figure 1.1.2.5-1). The procedures used on these 675 miles of pipeline will be " ... conventional techniques that have been widely used ..." (CAGPL, 1974, 13.a.6.1, p. 26). Table 1.1.2.6-1 presents a list of the main construction procedures in the order they will be executed.

Conventional Winter Construction Zone

Construction will center around the winter months in the approximately 1,010-mile portion of the 48-inch Main Line extending from Caroline Junction to the vicinity of 65° N. latitude (CAGPL, 1974, 13.a.6.1.B, p. 27). Although preconstruction surveys and some clearing and preparatory work might be done during spring and summer, pipe stringing, ditching, lowering and backfilling will be accomplished after freeze-up, when the roads and the working sides of the right-of-way will be frozen deep enough to bear heavy traffic.

Arctic Winter Construction Zone

The arctic winter construction zone encompasses all of the approximately 740 miles of the proposed route north of 65° N. latitude. In this region, in addition to winter construction of the pipeline, most stockpiling, mobilization and preparation will be undertaken during the winter preceding the construction winter. Moreover, some construction procedures will be modified in order to minimize vegetation and terrain disturbance that could lead to permafrost thawing. These modified construction procedures are noted in the facility construction descriptions that follow.

Pipeline

The major steps (Table 1.1.2.6-1) in building the proposed pipeline are: (1) locating and preparing the right-of way, (2) marshaling pipe and equipment along it, (3) assembling and burying the pipe, and (4) readying the finished pipeline for use. Except for those variations prescribed by construction zones, the procedures used will be about the same everywhere in that the pipeline will be built in the conventional, below-grade construction mode (Figure 1.1.2.3-1). Somewhat different construction procedures will be employed at places where the mode will not be conventional, particularly at facilities and river crossings.

Conventional Below-Grade Mode

Surveys along the proposed route will be the first physical activity in pipeline construction. Orthophoto mosaics will be used for preliminary location studies (AAGPC, 1975, p. 35). An on-the-ground location survey will follow during which the boundaries of the pipeline right-of-way and the

Table 1.1.2.6-1 Generalized sequence of construction procedures for buried gas pipeline

---

1. Preparatory activities
    - Location survey
    - Road construction
    - Construction survey
    - Clearing
    - Rock excavation
    - Grading
    - Mobilization*
    - Pipe stringing

2. Installation
    - Ditching
    - Bending*
    - Welding*
    - Coating*
    - Lowering*
    - Weighting and anchoring
    - Backfilling

3. Post-installation
    - Cathodic protection*
    - Testing
    - Clean-up
    - Restoration
    - As built survey
    - Legal survey

---

*Construction steps involving mainly work on the pipe; not interactive with the natural surroundings to any significant extent, and not, therefore, discussed in text.

Source: CAGPL, 1974, 13.a.6, p. 26-59; 13.a.7, p. 60-62; 13.a.2.3.1, fig. 2-10.

facility sites will be flagged. Survey paths 8 to 12 feet wide will be cleared of timber or brush.

The construction of roads for communication between the right-of-way, stockpiles, campsites and logistic portals, as well as the preparation of the working lane of the right-of-way, will be approximately concomitant with clearing operations in forest and brushland. The winter roads that are planned for the conventional winter construction zone will be built by clearing with bulldozers, grading, and waiting for freezeup. Useful timber and brush will be stacked along the right-of-way for sale or local disposal; slash will be burned and the ash buried. The snow roads to be used in the arctic winter construction zone will be built by grading and packing a snow embankment on the undisturbed ground surface. Clearing in the Arctic will be accomplished by hand or by using bulldozers equipped with shoes (devices fixed to the blade to insure it remains above the ground surface) that would limit gouging of the soil surface. Waste brush and timber will be burned on special incinerator sleds or at locations where ice-rich permafrost does not exist.

In areas where the pipeline will be buried in solid bedrock, trenching will be undertaken in advance of right-of-way grading and other final preparatory activities. By adjusting shothole configurations and charges, attempts will be made to control overbreak and limit splatter to the right-of-way (CAGPL, 1974, 13.a.6.5.4, p. 41).

In summer and conventional winter construction zones, the pipeline right-of-way will be graded by a combination of cutting and filling techniques. In the arctic winter construction zone, however, the working lane will be formed mainly by applying snowfill to the undisturbed ground surface (CAGPL, 1974, 13.a.6.5.1, p. 39). Ditch spoil or borrow over snow or ice will be used if sufficient natural snow is not available. Where cutgrading has to be used, restoration and erosion control measures will be instituted (CAGPL, 1974, 8.b.1.3).

Stringing the pipe consists of transporting double joints of pipe to the right-of-way and placing them in assembly position alongside the ditch centerline. In conventional construction areas, pipe will be moved along access roads and onto the right-of-way by trucks, tracked equipment, or all-terrain vehicles. In the arctic construction zone, this movement will take place over snow or ice roads. Openings will be left between joints of pipe at selected places in order to accommodate cross-route movement of animals, people, farm machinery, and construction equipment. The distance between major openings in undeveloped areas will not exceed 2,000 feet (CAGPL, 1974, 13.a.6.5.2, p. 39).

Installation of the proposed pipeline consists of a number of steps (Table 1.1.2.6-1) that reduce to digging a burial trench, putting the pipe together, placing it in the trench, and covering it up. Of these steps, only trenching and backfilling result in modification of the natural environment.

The pipe burial trench will be about 8 feet wide and 7 feet deep. Where practical, wheel trenching machines operating from the working lane excavate the trench; in areas of solid bedrock, obdurate permafrost, or other soil conditions unsuitable for the use of wheel trenchers, combinations of blasting, ripping, and backhoeing will be used. Trenching will be done after pipe stringing, bending, welding, and coating. In the summer construction zone and the conventional winter construction zone--where the bottom of the trench will be below the limit of seasonal frost--continuous foundation support for the pipe will be obtained by shaping the trench bottom. In solid bedrock and permanently frozen soils in the arctic winter construction zone, the pipe will be bedded on select material obtained from borrow or processed spoil.

Another provision of the construction procedures to be followed in the arctic winter construction zone is removal of the upper 18 inches of tundra sod before trenching and its replacement after backfilling (CAGPL, 1974, 13.a.6.5.4.B, p. 41). During lowering and backfilling, the tundra sod will be stockpiled outside of the spoil berm on the nonworking half of the right-of-way. An artist's conception of right-of-way configuration at the time of pipe lowering is reproduced as Figure 1.1.2.6-1 (CAGPL, 1974, 13.a.6.4.1, Figure 1).

Just before backfilling, rock shields or select borrow padding may be placed around the pipe to protect the coating and wrapping from damage by sharp gravel or frozen spoil. Then spoil or select backfill material (Section 1.1.2.3) will be pushed into the trench and shaped in a crown above the pipe centerline. Drainage gaps will be left across the backfill mound at intervals prescribed by watercourses and terrain conditions (Section 1.1.2.3 and Table 1.1.2.3-2). In arctic winter construction areas, replacement of the tundra sod will complete the backfilling process. In summer and conventional winter construction zones, the right-of-way and backfill mound will be fertilized and seeded during the summer following construction (CAGPL, 1974, 13.a.6.8, p. 58).

Post-construction activities along the proposed pipeline include installing cathodic protection systems, pressure testing, clean up, restoration, and final surveying. Cathodic protection, although extremely important in maintaining pipe integrity, will have little direct interaction with the natural environment.

Pressure testing will be done by filling a segment of the pipeline with a fluid which can then be pressurized and monitored for periods of several hours to several days. If pressure testing is done before freezeup in the summer and conventional winter construction zones, water will be the test medium. In the arctic winter construction zone and in testing after freezeup in other areas, either heated water or water containing a freezing point depressant will be used (CAGPL, 1974, 13.a.7, p. 61). The Applicant suggests that methanol will be the freezing point depressant, diluted with water to concentrations of 26 percent or less (CAGPL, 1974, 13.a.7, p. 61 and Figure 1).

After testing a segment of the pipeline, the water-methanol mixture will be taken to another test segment or discharged to the surroundings. If the test medium is discarded, it will be pumped to watercourses or sprayed over snowfields after diluting or distilling to obtain methanol concentrations of 1 percent or less (CAGPL, 1974, 13.a.7, p. 61). Prior to gas transmission, final drying of the pipeline will be accomplished by pushing a slug of methanol constrained by pipeline pigs through the pipe. This methanol will be similarly diluted or distilled before discarding.

Through cleanup activities, fences and roads will be returned to preconstruction conditions, combustible and other waste material collected and burned or buried, and damaged trees felled. In the arctic winter construction zone more elaborate procedures will be used including burning on incinerator sleds or sites not underlain by ice-rich permafrost, forming an insulating cover along the right-of-way by placing brush felled during clearing, and using abandoned borrow pits as burial sites for ash, noncombustible waste, and excess spoil (CAGPL, 1974, 13.a.6.7, p. 56).

Restoration and revegetation consist of aerial seeding and fertilizing of the rights-of-way of the pipeline and abandoned roads and hand planting

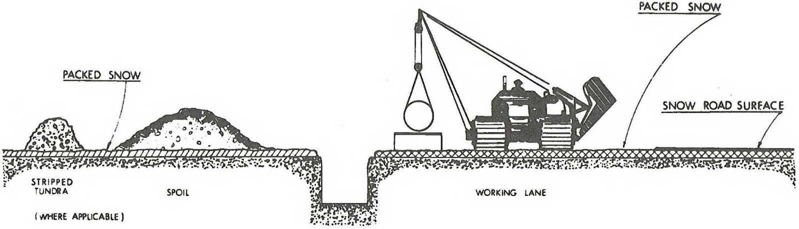


Figure 1.1.2.6-1 Cross-section configuration of the proposed right-of-way at the time of pipe lowering

shrubs on cut slopes and other areas requiring erosion control measures (CAGPL, 1974, 13.a.6.8, p. 57). Abandoned borrow pits will be graded to subdue relief before topsoil placement, seeding, and fertilizing.

The final element in construction of the buried pipeline will be completing the "as built" and legal surveys that are required during operation and maintenance and for cadastral purposes.

Special Construction Modes

In passing beneath rivers and other transportation facilities such as roads and pipelines, the proposed pipeline departs from the conventional buried configuration. The construction procedures by which this will be done are outlined in the following paragraphs.

River Crossings

At river crossings, pipe from the stockpile--already coated and jacketed with articulated concrete weights--will be brought to one bank of the stream to be welded into sections 500 to 1,000 feet long. Once a section is assembled, it will be equipped with flotation collars and pulled partly across the river by a cable and winch anchored to the opposite bank. Passage will be halted at a point along the length of the section in order that succeeding sections of pipe can be welded to the first. After spanning the river, flotation collars will be removed and the sinking pipe guided into the ditch excavated in the streambed. Backfilling will complete the installation.

Variations in the general procedure will be developed in response to differences in streambed configuration and riverbank geometry (CAGPL, 1974, 13.a.6.5.11, pp. 49-51). In the preferred procedure, pipe section fabrication will be done on the riverbank. If the stream is shallow, or the approach from the bank formidable, pipe section fabrication may be done from a berm built on the river bed and reaching as much as one-third of the way across the stream. If the river is too deep for practical berm construction, a series of anchored, linked barges may be extended from one bank to provide a pipe assembly area. Both the berm and the barges will be removed upon completion of the construction.

The Mackenzie River, at Swimming Point, and the Peel River will be crossed by construction procedures utilizing fabrication on the riverbank. The Mackenzie crossing, at Point Separation, and the Great Bear River will be crossed using either the berm or barge method (CAGPL, 1974, 13.a.6.5.11, p. 48). No crossing procedures have been designed for proposed pipeline crossings of the major rivers south of 60° N. latitude.

Crossings of smaller watercourses not considered major rivers will be executed during the winter months when streams are iced over and flow greatly reduced. These stream crossings will be built by the Main Line construction crews using conventional pipe-laying equipment positioned on the ice (CAGPL, 1974, 13.a.6.5.11, p. 51). If the streams are too deep to be crossed by conventional construction procedures, a scaled-down version of the major river crossing method will be used.

Road, Rail, and Foreign Pipeline Crossings

Crossings of minor roads will be by open cut with continued traffic passage accommodated by detours or temporary bridges. The pipeline will be encased in a protective pipe 56 inches in diameter. Bored and cased crossings will be made beneath major roads, highways and railroads so there will be no disruption of traffic (CAGPL, 1974, 13.a.6.5.12, 51). Foreign pipeline crossings will be constructed as stipulated by the pipeline owner; minimum clearance will be 12 inches and cathodic protection systems will be installed.

Pipeline at Stations, Valves, and Scraper Traps

No major departures from the procedures used in burying the pipe in the conventional mode will be required at compressor, refrigeration, or measurement stations, or near block valves and scraper traps. At facilities where the pipe will be brought from the ground, ditches may be more shallow, in response to vertical bends, and wider, to accommodate pipe-restraining weights and anchors.

Compressor Stations

The design of the compressor stations as described in section 1.1.2.3 (Facilities) notes the essential role they will play in construction and operation of the proposed pipeline system. The sites, which will be identified by the location surveys during the first construction year, will serve as stockpiles, campsites and logistic portals for Main Line construction for periods of 1 to 4 years before station construction begins. After construction and the onset of gas transmission, the stations will serve as primary system control points and maintenance bases in addition to their primary functions of pressurizing and chilling natural gas.

The first step in the construction of compressor stations will be clearing and grading by conventional methods. In the arctic winter construction zone, where foundation soils are perennially frozen, a pad of select fill with a 6-inch gravel surface will be built on the site. Detailed site investigations will determine the thickness of the pad required to maintain the 32° F isotherm within the fill (CAGPL, 1974, 13.a.6.6, p. 55). Thick fill pads will not be required at many sites in the summer and conventional winter construction zones.

Water supply, sewage treatment, and waste disposal facilities will be developed nearby, as described in section 1.1.2.3, and stockpile and campsite functions will commence. Camp buildings will be modular in design, fabricated elsewhere, and placed on temporary foundations. Operations and maintenance bases to be built at the compressor station sites will be scheduled for completion at the same time as the adjacent pipeline segments.

Onsite construction of compressor and refrigeration plants consists of the assembly of modular components to the greatest extent possible (CAGPL, 1974, 13.a.6.6, p. 56). Heavy machine, piping, and electronic components will be fabricated, assembled and tested at offsite locations--probably at the Hay River staging area for station sites in the arctic winter construction zone and at unspecified southern Canada locations for sites in the summer and conventional winter construction zones. Barge transportation of components is planned for most station sites north of Fort Simpson (Figure 1.1.2.2-1).

Buildings will be of insulated steel construction and prefabricated design. Raft foundations will be used at most summer and conventional winter construction sites; piling foundations will be employed at arctic winter construction sites where foundation studies show the presence of thaw-susceptible permafrost soils.

Roads

The construction procedures to be used in the development of winter trails, snow or ice roads, winter roads, and permanent gravel roads are described in section 1.1.2.3 (Facilities). All types of roads require location surveys and right-of-way clearing. Winter trails and snow and ice roads will not, in general, entail grading, filling, and culvert installation. Constructing winter roads in the conventional winter construction zone requires cut-grading; post construction restoration, revegetation, and erosion control measures will therefore be required. Conventional procedures will be used to construct permanent gravel roads in summer and conventional winter construction zones. In the arctic winter construction zone, however, permanent road construction entails fill-grading rather than cut-grading, extensive culvert installation, and a variety of restoration and erosion control measures.

Airstrips

The 21 airstrips to be constructed in conjunction with the proposed pipeline sytem will individually require borrow materials in amounts ranging up to 1.2 million cubic yards (CAGPL, 1974, 13.a.2.2, drawing IC-0211-1002). Airstrip construction, therefore, will begin with location surveys and the identification and development of extensive borrow-mining facilities. The airstrip sites will be cleared and fill- or cut-graded according to the permafrost-caused foundation problems identified by site studies. Heavy duty roads to borrow pits will be developed and gravel will be brought to the airstrip site for placement by the "dump and spread" method. On thaw-susceptible permafrost soils in the arctic winter construction zone, the fill embankment will be constructed to thicknesses adequate to maintain the 32° F isotherm above the soil level (CAGPL, 1974, 8.b.1.4.5, p. 20); elsewhere the fill thickness required will be that needed to form a suitable landing surface. The airstrip embankment probably will be surfaced with select gravel. At each airstrip, the multipurpose building needed will be of insulated steel, prefabricated design, and placed on raft or piling foundations. Airstrip development generally is scheduled for completion during the first or second construction year.

Communications Sites

The Applicant supplied little information on the construction procedures to be involved in the building of the approximately 80 communications towers required by the proposed pipeline system at compressor stations and intermediate locations.

In the arctic winter construction zone, conceptual design drawings (CAGPL, 1974, 8.b.3, sheet E-1) show gravel pads at communication sites ranging from 1.5 to 5.0 feet in thickness according to whether or not thaw-susceptible soils are encountered. Pipeline route maps (CAGPL, 1974, 13.a.2.2) show many off-station communications sites connected by short winter trails to nearby borrow sites. Presumably, therefore, communication site construction will commence in the winter with location surveys, clearing and grading, and borrow mining, transporting and spreading. Most sites will have gravel helipads constructed no more than a few hundred feet away. Prefabricated steel buildings required at tower sites on thaw-susceptible permafrost soils will have piling foundations allowing 12 inches of air space below the building and above the surface of the gravel pad. Elsewhere, piling foundations will not be required.

Although most components of communications sites presumably will be fabricated offsite and transported to the location by ground or air means, it is unknown whether the 205-foot steel towers will be built inplace or whether they will be fabricated onsite or elsewhere and erected using helicopters.

Wharves

After site selection and surveying, the first step of development at wharf and stockpile locations is clearing of the 25-acre site and camp construction. Clearing will exceed the actual-use limits of the site by a distance of 100 feet in order to provide a buffer zone against accidental fires. Roads and borrow pits then will be developed followed by grading of the approaches to the riverbank. After driving steel sheet piling to form the face of the wharf, the area behind it will be filled and surfaced with gravel. Sinking the fuel barge mooring caissons is to be carried out approximately simultaneously. The last stages of preparation will be erecting storage buildings, tanks, and piping components and constructing the explosive magazine.

Human Resources

The Applicant's estimate (CAGPL, 1974, 13.a.5.0, Figure 1) of manpower requirements by skill type and construction year need is reproduced in Figure 1.1.2.6-2. On the order of 15,000 total man-years will be required to construct the proposed pipeline system through the summer of the fifth construction year.

Although the ratios between work force skill types will be approximately constant, total manpower requirements will show large variations between some succeeding intervals of one-half construction year duration. For example, between the summer of construction year 4 and the winter of construction year 4-5--when the Prudhoe Bay Supply Line will be built--the total manpower requirement increases from approximately 1,750 to about 5,000. By the following summer, the work force requirement drops to less than 1,500 men.

Peak employment for the proposed construction occurs in the interval between the summers of years 2 and 4 when between 5,400 and 7,500 persons will be working. The period of peak employment corresponds to the scheduled construction of the Main Line and the Richards Island Supply Line.

1.1.2.7 Operational, Maintenance, and Emergency Procedures

Command of the functioning proposed pipeline system will be exercised from a Gas Control Center located at Calgary and, to a lesser extent, from five operation and maintenance district headquarters located along the pipeline route. The gas transportation system is planned for remote control operation in which computers, electronic communications, and aircraft logistics are essential elements.

Operations

The Gas Control System to be operated from the Gas Control Center links the Center, compressor and measurement stations, and the district headquarters. The Applicant's conceptual diagram of the system is reproduced as Figure 1.1.2.7-1.

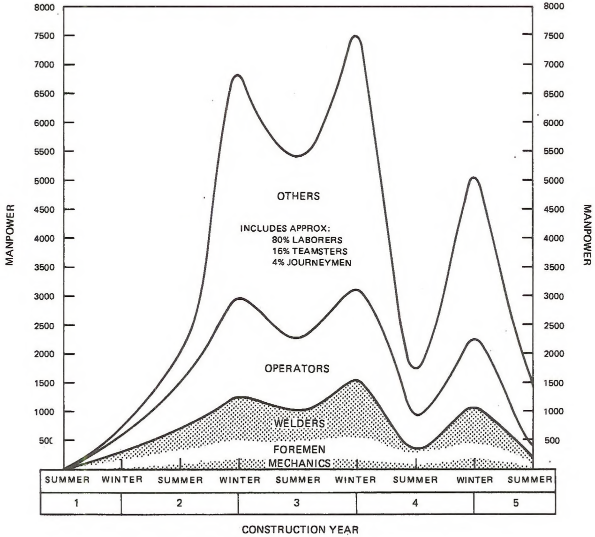


Figure 1.1.2.6-2 Construction manpower requirements

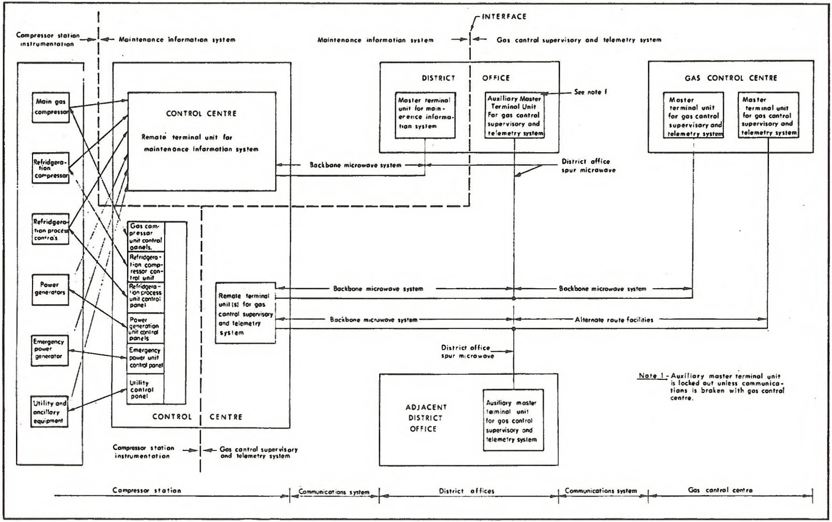

INTERFACE
Compressor station instrumentation
Maintenance information system
Maintenance information system
Gas control supervisory and telemetry system
DISTRICT OFFICE
Master terminal unit for maintenence information system
Auxiliary Master Terminal Unit For gas control supervisory and telemetry system
See note 1
GAS CONTROL CENTRE
Master terminal unit for gas control supervisory and telemetry system
Master terminal unit for gas control supervisory and telemetry system
Main gas compressor
Refridgeration compressor
Refridgeration process controls
Power generators
Emergency power generator
Utility and ancillary equipment
CONTROL CENTRE
Remote terminal unit for maintenance information system
Backbone microwave system
District office spur microwave
Gas compressor unit control panels.
Refridgeration compressor control unit
Refridgeration process unit control panel
Power generation unit control panels
Emergency power unit control panel
Utility control panel
Remote terminal unit(s) for gas control supervisory and telemetry system
Backbone microwave system
Backbone microwave system
Backbone microwave system
Alternate route facilities
District office spur microwave
ADJACENT DISTRICT OFFICE
Auxiliary master terminal unit for gas control supervisory and telemetry system
Note 1 - Auxiliary master terminal unit is locked out unless communications is broken with gas control centre.
CONTROL CENTRE
Compressor station instrumentation
Gas control supervisory and telemetry system
Compressor station
Communications system
District offices
Communications system
Gas control centre

Figure 1.1.2.7-1 Conceptual diagram of Gas Control System

The Gas Control System will start and stop compressors and gas chilling units; monitor, record, and analyze gas temperature, pressure and quality; and adjust these quantities by tailoring station operating parameters. At compressor stations, pipeline pressures will be controlled by varying the speed of the gas compressor turbines, and gas temperatures by varying the amount of heat removed by chilling or cooling facilities (CAGPL, 1974, 8.a.4.3, p.13). At measurement stations, data to be monitored include absolute line pressure, pressure differential, temperature, specific gravity, water and hydrocarbon dewpoints, component analyses, and heating values (CAGPL, 1974, 13.b.5.5.1, p.24). These data will be collected automatically and telemetered to the Gas Control Center where they are received, stored, and analyzed by computer.

Maintenance

Maintenance of the proposed natural gas transportation system will be organized on a geographical basis, as shown in Figure 1.1.2.7-2. The Northern Division consists of the Inuvik, Norman Wells, and Fort Simpson Districts; the Southern Division includes the Peace River and Calgary Districts. A major physical facility devoted to maintenance will be located in each district (CAGPL, 1974, 13.b.3.3, p.15).

The system facilities to be maintained are the compressor and measurement stations, the pipeline, block valves, and other aboveground structures, access roads and airstrips, corrosion and cathodic protection systems, and waste disposal and water treatment plants. In addition, the landscape alterations made during construction will require inspection and maintenance.

The requirements for maintenance are people and equipment to do it and a maintenance strategy that tells when and how it must be done.

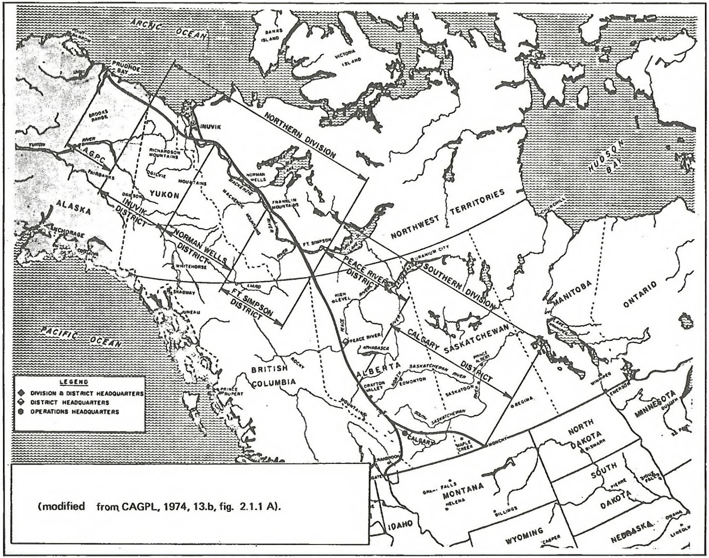
Manpower

Estimated manpower requirements for maintenance purposes in the fifth operating year--when 4.5 bcf/d throughput will be attained--are listed in Table 1.1.2.7-1. A total of 390 persons will be employed in the maintenance work, distributed into districts as follows: Inuvik, 70; Norman Wells, 66; Fort Simpson, 63; Peace River, 80; Calgary, 111. The skill type for which there will be greatest requirement is termed technician.

To some extent, the requirements for maintenance personnel will be met by hiring "Northern residents" (CAGPL, 1974, 13.b.2.1.2, p. 6) who will become skilled through a variety of training programs (CAGPL, 1974, 14.f). The pipeline system corporation will provide housing, medical, and recreational facilities or assist its employees in obtaining them (CAGPL, 1974, 13.b.2.2, p. 7-8).

Equipment

In addition to expendable supplies, such as paint, fuel, lubricants, borrow and pipe, maintenance of the proposed pipeline system will require a sizable inventory of transportation and work equipment. Tables 1.1.2.7-2 and -3 provide estimates of the ground and aircraft equipment required. Ground equipment consists mainly of transportation vehicles needed to move men, supplies and equipment to places requiring maintenance and repair, and heavy-duty work equipment to be used on the pipeline, airstrips, and access roads. The ground equipment will be positioned at from 6 to 12 maintenance



(modified from CAGPL, 1974, 13.b, fig. 2.1.1 A).

Figure 1.1.2.7-2 Proposed operations and maintenance districts

Table 1.1.2.7-1 Estimated personnel required for maintenance by operating district and skill type in fifth operating year

skill type	Northern Division Inuvik	Norman Wells	Fort Simpson	Southern Division Peace River	Calgary	Total
district superintendent	1	1	1	1	1	5
district engineer	1	1	1	1	1	5
pilot	2	1	1	1	1	6
flight engineer	2	1	1	1	-	5
clerical	4	4	4	4	4	20
maintenance supervisor	1	1	1	1	1	5
foreman	2	1	1	2	5	11
mechanic	4	4	4	3	5	20
operator	6	4	4	5	7	26
welder	3	3	3	3	5	17
maintenance man	12	8	8	11	14	53
chief technician	1	1	1	2	3	8
technician	31	36	33	45	64	209
total	70	66	63	80	111	390

---

source: CAGPL 1974, 13.b, tables 2.1.2.D and 2.1.2.E

Table 1.1.2.7-2 Estimated ground transportation and work equipment for maintenance purposes, by district

	Northern Division			Southern Division		
	Inuvik	Norman Wells	Fort Simpson	Peace River	Calgary	Total
personnel carriers	89	24	21	51	34	219
backhoe, 1-1/2 yd^3	3	1	1	1	4	10
sideboom	19	6	7	6	8	46
bulldozer	12	5	6	4	8	35
snow sled	10	3	3	2	-	18
tandem tractor truck	1	2	2	2	4	11
highboy trailer	1	1	1	2	4	9
lowboy trailer	1	2	2	1	3	9
propane trailer	1	1	1	-	-	3
LGP vehicle, 10-ton	10	3	5	3	-	21
LGP vehicle, 40-ton	10	3	3	3	-	16
LGP vehicle, backhoe and blade	10	5	3	5	1	24
LGP trailer	17	3	5	4	1	30
truck, 5-ton with hydraulic crane	4	2	1	2	-	9
trucks, various special purpose	6	6	4	5	8	29
grader and snowplow	10	6	5	7	5	33
LGP crane, 20-ton	4	1	2	3	2	12
tractor backhoe loader	10	6	5	12	8	41
air cushion vehicle	1	-	-		-	1
excavator, rubber tired	-	-	-	2	1	3

Source: CAGPL, 1974, 13.b, Tables 3.1.1.A-E and CAGPL, 1975, Appendix F.

Table 1.1.2.7-3 Anticipated aircraft requirements

description	cruising speed	range	payload	purpose
short-take-off and landing airplane, owned	150	600	4,000	transport men and/or materials
small airplane, owned	100	700	600	line patrol
stern-loading cargo airplane, charter as needed	300	1,800	45,000	re-supply and emergency equipment transport
helicopter, passenger, owned	125	300	1,200	transport personnel and equipment
helicopter, cargo, owned	125	-	8,000	move equipment and personnel

source: CAGPL, 1974, 13.b 3.2.1, p 12-13 depots--mostly compressor stations--in each district (CAGPL, 1974, 13.b, Tables 3.1.1, A-E).

Aircraft will be used for resupply, transportation of men and equipment, and inspection and surveillance.

Maintenance Strategy

The essentials of any maintenance strategy are (1) methods of monitoring and analysis that yield predictions of malfunctions and (2) sets of worked-out responses that can be executed in the face of predicted malfunctions. The major classes of work that must be planned for in maintenance strategy are routine or preventive maintenance, and nonroutine or remedial maintenance. Special cases of remedial maintenance are unpredicted major system malfunctions--line breaks and fires, for example--for which complex contingency plans are developed.

Preventive Maintenance

For the proposed pipeline system, the basis of the preventive maintenance program is previous pipeline experience, manufacturer's specifications for system components, and the operational history of the pipeline. Plans for this work will be specified in a comprehensive "operations and maintenance procedures manual" (CAGPL, 1974, 13.b.1.0, p. 3) to be developed and written toward the end of the construction phase of the proposed project. The responsibility for executing the preventive maintenance program is lodged at the district level (Figure 1.1.2.7-2). Manpower will be transported by aircraft from the district headquarters to the appropriate airstrip, and from the airstrip by ground vehicles or helicopters to maintenance sites and supply and equipment depots that usually will be compressor stations. The major facilities requiring preventive maintenance are compressor, refrigeration, and measurement stations; block valves; scraper traps; aboveground piping; corrosion and cathodic protection systems; communication towers; and waste disposal and water treatment plants. The work involved ranges from painting buildings and aboveground piping to lubricating and chart changing at stations and checking corrosion coupons and measurement probes along the buried pipeline.

Remedial Maintenance

The basis of the remedial maintenance program will be (1) inspections by company personnel using ground or air support and (2) system monitoring and analysis by the computer-based Maintenance Information System. The responses to discerned or predicted malfunctions will be specified in the "operations and maintenance procedures manual." Since the facilities of the pipeline system are planned for remote operation, the remedial maintenance strategy depends heavily upon a smoothly functioning communication system, and upon the effectiveness of aircraft logistics.

Proposal documents supply little information on either frequency or criteria of the planned inspections. The pipeline right-of-way will be inspected from the air regularly, using fixed- or rotary-wing aircraft flying at altitudes of 100 to 150 feet generally, and up to 500 feet exceptionally. Flight frequencies may be as low as once or twice per month in lowland areas with low population densities (CAGPL, 1974, 13.b.3.2.2, p. 14) or as high as weekly over areas where geotechnical problems can be anticipated during certain seasons of the year. When wildlife would be disturbed by aircraft, ground patrols will be made on foot or using suitable vehicles (CAGPL, 1974, 13.b.5.4.2, p. 23).

Compressor and refrigeration stations will be inspected on a "routine basis" (CAGPL, 1974, 13.b.5.3, p. 21), with inspecting personnel brought to the stations by aircraft. One to three flights per week may be required (CAGPL, 1974, 13.b.3.2.2, p. 14). Gas measurement stations will be inspected weekly by personnel who will change data recording charts and zero the gas measurement instruments (CAGPL, 1974, 13.b.5.5.2, p. 24).

Main Line block valves and valve operators will be "tested and operated on a routine basis" (CAGPL, 1974, 13.b.5.4.5, p. 23).

Internal pipe corrosion will be inspected by routine study of corrosion coupons and measurement probes (CAGPL, 1974, 13.b.5.4.3, p. 23).

Inspection of communication towers at compressor stations and intermediate points will include "physical examination of supporting structures, the tension of guy wires and the condition of foundations" (CAGPL, 1974, 13.b.5.4.5, p. 24).

Sewage will be regularly tested, and treated water will be routinely monitored, to insure compliance with government standards on the one hand and potability on the other (CAGPL, 1974, 13.b.5.6.1, p. 25, and 13.b.5.6.2, p. 26).

In conjunction with right-of-way line patrols, designated environmental inspectors will study landscape changes, restoration efforts, and revegetation progress. Unstable slopes will be "monitored and checked" regularly (CAGPL, 1974, 13.b.5.4, p. 22), changes in drainage and erosion conditions will be viewed, and gaseous emissions and potential pollutants will be identified (CAGPL, 1974, 14.d N6.1.2, p. 5).

For the proposed pipeline system, a major element in the maintenance strategy is the "Maintenance Information System," which the Applicant (CAGPL, 1974, 13.b.1.0, p. 4) defines as:

> ... the system whereby data concerning essential performance parameters of major items of equipment installed at the compressor stations are automatically gathered and telemetered to the responsible District Officer where, they are recorded and used to develop programs for preventive and routine maintenance of such equipment.

Detailed information on the system or the parameters it will monitor has not been provided.

The Maintenance Information System will be computer-based and have much in common with the computer and sensing components of the Gas Control System. A master terminal unit will be located in each district office and connected by "assigned data circuits" (CAGPL, 1974, 8.b.7.4.0, p. 5) to remote terminal units located at the compressor stations assigned to each district. Data on equipment performance, such as gas temperature and pressure, turbine compressor performance, bearing oil temperature, and vibration characteristics (CAGPL, 1974, 13.b.5.3, p. 20) will be collected automatically and telemetered to the district office. There it will be averaged, subjected to trend analysis, or otherwise statistically manipulated to enable comparison with previously established operating norms. In addition, the Maintenance Information System will "signal and record all station upset conditions and operational changes made by Gas Control Center" (CAGPL, 1974, 13.b.5.3, p. 20) and collect weather information from weather monitoring systems at airstrips (CAGPL, 1974, 8.b.7.4.0, p. 5).

Data and analyses from the Maintenance Information System will be used to determine the need for maintenance. The procedures to be executed will be specified in the operations and maintenance procedures manual.

Contingency Planning

Unpredicted major system malfunctions, like line breaks and fires or explosions at compressor stations, will be subjects of contingency planning (CAGPL, 1974, 13.b.6.0, p. 26-33). Such plans, if available, adequate, and properly executed, accelerate the damage assessment, mobilization, and repair required in the event of a sudden breakdown in gas transmission. Contingency plans have not been developed for the proposed pipeline project but will be formulated late in the construction phase, prior to the onset of transmission.

Because of the large variations in terrain, accessibility, and climate along the proposed pipeline route, different contingency plans will be prepared for different portions of the system. The planning increment probably will be the section of the pipeline between adjacent compressor stations (CAGPL, 1974, 13.b.6.1.2, p. 26).

The plans for each section will be developed from a variety of land and project data compiled during the construction of the line segment (CAGPL, 1974, 13.b.6.1.2, p. 26). Included will be:

- "final line route and profile references to survey markers and topographic features;
- location of access roads to right-of-way;
- location of facilities such as compressor stations, meter stations, camps, communications, Main Line block valves, pipeline mileposts, airstrips and associated access roads;
- type of terrain, vegetation and subsurface soils encountered during construction;
- depth of line covers, types of backfill material and details of special construction provisions for road and water body crossings, erosion and buoyancy control, and revegetation of line cover;
- location and size of backfill material storage sites and borrow areas;
- hydrological data including local drainage patterns and the location of water bodies suitable for aircraft use; and
- referenced data sheets specifying local environmental concerns and related protective measures."

The contingency plans for each section will also include data on equipment and supply inventories, governmental authorities that have to be notified, environmental constraints on repair procedures, operational and logistical requirements, site arrangement plans and repair schedules (CAGPL, 1974, 13.b.6.1.2, p. 27).

- "location and content of the equipment storage depot nearest to the line section and of the next adjacent storage depots;
- optimum routing and method of transportation of men and equipment from these depots to various points on the line section, having regard to different seasonal environmental constraints;
- lists of terrain protection mats, hand tools, lightweight equipment units, portable service, shelter and camp units, pre-packed and grouped for helicopter transport from the storage depot to the repair site;
- lists of the locations and quantities of pre-tested pipe lengths, heavy repair equipment units with loading and dispatch sequences for their transport by road haul units and/or low-ground-pressure units;
- schedules of the fuel supply requirements of the equipment to be used in the repair operations;
- lists of regional contractors outlining their capability of possible assistance in line repair procedures;
- lists of owners and occupants of lands traversed by the line section;
- lists of regional agents of government bodies (for example, land use and law enforcement) to be notified in emergency situations;
- identification of specific local human and environmental concerns and procedures for emergency use of land adjacent to the right-of-way;
- the site-specific data forming part of the Alignment Sheets;
- specific assignment of two senior supervisors from the District, one in charge of all operations at the repair site, and the other responsible for the logistics of the repair operation, including the mobilization scheduling and dispatching of men, materials and equipment to the site, the reporting of progress to the Gas Control Center, and the securing and co-ordinating of the activities of any contractors used in the repair;
- site arrangement plans which will specify the position and placement sequence of: terrain protection mats; temporary communications towers; portable camp units; shelters for work area, tools and materials; power generators and lighting standards; testing, air compression, pumping and fire extinguishing equipment; fuel storage units; and work equipment areas;
- schedules for the mobilization, dispatch, transport and working shift rotation of personnel from District (and, in an extreme case, from adjoining Districts) required to effect repairs of various magnitude;
- standby arrangements and notification procedures for any potential contracted supply of services."

Certain design provisions will be important factors in controlling the consequences of major malfunctions of pipeline system components. In the event of a line break, for example: (1) the Main Line block valve nearest to the rupture will close automatically, (2) the continuous monitoring of station pressure at the Gas Control Center will register an alarm condition and provide the locations of the compressor stations adjacent to the break, and (3) the compressor stations upstream and downstream of the break will shut down automatically (CAGPL, 1974, 13.b.6.1.4, pp. 28-29). Similarly, fires at compressor stations--which will be detected by fire-sensing photoelectric eyes and heat rise detectors--will activate an emergency shutdown system to: (1) generate fire alarms at the station, Gas Control Center, and Maintenance District Headquarters, (2) shut off all station operating units, (3) isolate the station from the rest of the pipeline, and (4) automatically smother the fire with an inert gas (CAGPL, 1974, 13.b.6.3.1, p. 32).

1.1.2.8 Future Plans

No direct discussion of future plans for the proposed natural gas transportation system has been provided.

The pipeline, if built, will be "... operative for many decades ..." because the "... gas reserves should last that long" (CAGPL, 1974, 14.d.6.5, p. 12). The Applicant notes that one transmission line in Alberta has been in service for over 60 years.

If and when abandonment does occur, (1) the buried pipe will be left in the ground, (2) surface facilities will be removed and salvaged unless required on location for other purposes, and (3) sites will be "... restored and returned to nature ..." (CAGPL, 1974, 14.d.6.5, p. 13).

Several design provisions of the proposed pipeline suggest that expansion of capacity is contemplated some time in the future. The 48-inch pipe selected for the supply lines, for example, is oversize for throughputs of 2.25 bcf/d but was chosen because transmission capacity can be raised to 4.5 bcf/d by merely adding more compression horsepower (CAGPL, 1974, 9.3, pp. 2-3). Conceptual drawings of compressor stations show outlines of second compressor, chilling, and cooling units (CAGPL, 1974, 8.b.3, sheet A-1) and a proposed route map shows sites for additional compressor stations on the supply lines that can be built at an unspecified, future date (CAGPL, 1974, 8.a.2, drawing 4-0214-1004). The capacity of each 48-inch supply line, therefore, can be increased to throughputs of 4.5 bcf/d without additional pipe-laying.

Increasing transmission capacity on the Main Line, however, will require compressor station construction and looping (building one or more additional pipelines adjacent and parallel to the first).

1.1.2.9 Actions Involved

The proposed pipeline in Canada crosses 1,150 miles of Federal Crown lands in the Yukon and N.W.T. and 1,285 miles of Provincial lands either owned privately by individuals or business entities, or owned by the governmental units, largely the Provincial Government. The basic pattern of governmental permits necessary for construction and operation of the proposed pipeline in Canada centers around the National Energy Board and the Department of Indian Affairs and Northern Development.

Federal

The National Energy Board

Since the proposed Canadian Arctic Gas Pipeline is an interprovincial undertaking which involves international commerce, it is subject to Federal Government jurisdiction. The provinces are not authorized, under Canadian law, to regulate the undertaking, nor to deny its creation or operation.

On March 21, 1974, the Applicant applied to the NEB (National Energy Board) for authorization, "Certificate of Public Convenience and Necessity", to construct and operate a natural gas pipeline in interprovincial and international commerce. The NEB conducted a hearing which began on October 27, 1975. The hearing involves oral cross-examination of witnesses who present testimony and in this particular proceeding NEB adopted the practice of receiving direct evidence in written form, in advance of the cross-examination session.

At the conclusion of the hearings a written decision will be prepared by NEB. That decision, if it denies the application, is final. If it approves the project, as filed or with modification, the decision is subject to review by the Cabinet of the Canadian Government, which makes the final decision. The decisions of NEB are essentially not subject to appeal to the courts, since the only grounds for appeal are exceeding the jurisdiction of the Board or willfully ignoring facts, in an extreme way. The decisions of the Cabinet are not subject to judicial review.

The Department of Indian Affairs and Northern Development

The proposed pipeline in the Yukon and Northwest Territories will be constructed entirely on federally-owned land. This land is held in the name of the Crown, under the administration of DIAND (Department of Indian Affairs and Northern Development).

Applications were filed with DIAND on March 21, 1974, for a right-of-way permit, involving an easement and leases or fee simple purchase of land to be used for aboveground facilities.

Consolidated Investigation and Decision

DINA has undertaken to try to produce a consolidated investigation and decision. Accordingly, it has developed procedures, in conjunction with other departments of the Canadian Government, for a consolidated examination leading to the issuance of all permits required under all appropriate statutes. This includes the Territorial Lands Act, the Fisheries Act, the Inland Waters Act and a few other less major and more locally applicable statutes and regulations. In this effort, the Department of Environment and the Department of Transportation have been consulting and coordinating with DINA.

Hearings

There is no requirement that the Minister of Indian Affairs and Northern Development hold hearings in order to exercise his authority under the various acts although he is empowered to do so and, in this case, has chosen to do so.

A hearing examiner, Mr. Justice Thomas Berger of the Supreme Court of British Columbia, has been appointed to take evidence relative to the proposed pipeline and its effects upon the territorial areas. Mr. Justice Berger's authority and his charge are to make recommendations as to the terms and conditions which should be attached to any right-of-way permit issued. He is not empowered to allow or deny the existence of the pipeline, nor even to make a recommendation relative thereto in his final report. His recommendations on the terms and conditions will go to the Minister of Indian Affairs and Northern Development, who in turn will formulate his decision with regard thereto, and will report the same to the Cabinet, for final review. The decision of the Minister and Cabinet is not subject to judicial review.

Provincial

Authorizations

Within the Provinces the Applicant must secure authorization from landowners to build a pipeline across their lands. The lands are basically of two kinds, those owned by private individuals or business entities and those owned by governmental units, largely the Provincial Government. Canadian Gas Arctic Pipeline Ltd. proposes to enter into negotiations for easements across the land desired with landowners in both categories. Satisfactory negotiation of easements is the long-standing pattern of the natural gas industry in Canada as well as the United States. Receipt of the National Energy Board Certificate relative to the pipeline will carry the right of eminent domain.

Application of Provincial Law

The proposed pipeline will be subject to Federal Government jurisdiction and the Provinces are not authorized, under Canadian law, to regulate the undertaking, nor to deny its creation or operation. The extent of the application of Provincial law is extremely limited, although there is a developing doctrine, similar to that in the United States, that in such fields as environmental protection and health and safety, Provincial jurisdiction may apply to a limited extent so long as not inconsistent with Federal statutes and regulations and does not prevent or unduly burden the operation of the interProvincial undertaking.

The application of this doctrine in either the Provincial or Federal case does not constitute a permit or authorization which the Applicant must receive, but rather pertains to the way that the pipeline must operate once it is in being: that is, in conformity with applicable Provincial and Federal laws. These laws range from conformity to the worker, health and welfare statutes, to vehicular speed regulations, the control of burning waste materials, disposition of liquid wastes, and others.

Pre-negotiation Information Needs

The Provinces of Alberta and British Columbia have indicated that before they begin to negotiate a right-of-way permit, they wish to secure more specific information relative to the proposed project in their territory. The Applicant has agreed to furnish such information on a cooperative basis, subject to the understanding that such cooperation does not constitute a waiver to the lack of jurisdiction of the Province.

Public Hearing Meetings

The Provinces have indicated that they may wish to hold a form of "public hearing meeting" before beginning negotiations for a right-of-way permit. The Applicant has indicated willingness to be cooperative, so long as the result does not introduce undue delay.

REFERENCES

Alaskan Arctic Gas Pipeline Company, 1975, Comments of Alaskan Arctic Gas Pipeline Company relative to Part III (Canada) of the Draft Environmental Impact Statement of the Department of the Interior regarding the Alaskan Natural Gas Transportation System: unpub., dated.

Canadian Arctic Gas Pipeline Limited, 1974, Application to the National Energy Board: application to the Government of Canada, Ottawa, Ontario, 19 p., schedule 1, and 2 maps.

Canadian Arctic Gas Pipeline Limited, 1974, Application to the Department of Indian Affairs and Northern Development: application to the Government of Canada, Ottawa, Ontario, 15 p. and schedule A.

Canadian Arctic Gas Pipeline Limited, 1974, Location, design and capacity of facilities (section 8) and connecting pipeline facilities (section 9): an exhibit in support of applications to the Department of Indian Affairs and Northern Development of Canada for authorization to use land and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, chapters individually paginated.

Canadian Arctic Gas Pipeline Limited, 1974, Cost of facilities (section 10) and Pro-forma financial statements (section11): exhibits in support of an application to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, sections individually paginated.

Canadian Arctic Gas Pipeline Limited, 1974, Construction Plan (section 13.a) and Operations and maintenance plans (section 13.b): an exhibit in support of applications to the Department of Indian Affairs and Northern Development of the Government of Canada for authorization to use land and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, chapters individually paginated.

Canadian Arctic Gas Pipeline Limited, 1974, Environmental statement, Canada-north of the 60th parallel (section 14.d N): an exhibit in support of applications to the Department of Indian Affairs and Northern Development of the Government of Canada for authorization to use land and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, chapters individually paginated.

Canadian Arctic Gas Pipeline Limited, 1974, Northerner training program (section 14.f): exhibits in support of an application to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, sections individually paginated.

Canadian Arctic Gas Pipeline Limited, 1974, Financing plan (section 15) and Prerequisite authorizations (section 16): exhibits in support of an application to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, sections individually paginated.

Canadian Arctic Gas Pipeline Limited, 1974, Responses to Pipeline Application Assessment Group Requests for Supplementary Information: report dated Oct. 2, 1974, p. 12-1 - 12-7.

Canadian Arctic Gas Pipeline Limited, 1975, Amendments to alignment sheets (section 8.a.3, pipeline routing in the vicinity of Fort Simpson), and design drawings (section 8.b.3, for certain major river crossings), unpaged.

Canadian Arctic Gas Pipeline Limited, 1975, Location of facilities (section 8.a), design and capacity of facilities (section 8.b), cost of facilities (section 10), pro-forma financial statements (section 11), construction plan (section 13.a), operations and maintenance plans (section 13.b), environmental statement (section 14.d): exhibits in support of an amendment to applications to resize delivery lines on the basis of contracted gas volumes, sections individually paginated.

Canadian Arctic Gas Pipeline Limited, 1975, Location of facilities (section 8.a), design and capacity of facilities (section 8.b), construction plan (section 13.a), and environmental statement (section 14.d): Exhibits in support of an amendment to applications to relocate the Main Line near Ft. Simpson and to dual certain river crossings; sections individually paginated.

2 DESCRIPTION OF THE EXISTING ENVIRONMENT

2.1 ARCTIC GAS PIPELINE PROJECT

2.1.2 Canadian Pipeline

2.1.2.1 Climate

The climate along the proposed pipeline route varies from coastal Arctic near the Beaufort Sea to continental in southern Alberta and the neighboring parts of Saskatchewan and British Columbia. Relief and other local factors cause many variations from regional norms. In general, winters are long and cold; summers are short and cool, but for limited periods of time may be hot. Spring and fall seasons are essentially nonexistent in the far north, but become distinct and progressively longer southward.

Temperature

Mean temperatures along the proposed route in summer are generally in the sixties (Fahrenheit) and in winter considerably below freezing. At Aklavik, N.W.T. (Northwest Territories) (on the Mackenzie Delta), daily mean temperatures reach a June high of 55° F to 60° F and a January low of about -20° F. The corresponding temperatures of other stations on or near the proposed route are: Ft. Norman, N.W.T. (on the Mackenzie River at 65° N latitude), 60° F and -15° F to -20° F; Olds, Alta. (near Calgary), 61° and 11.9°; Cranbrook, B. C. (near Kingsgate), 64.4° F and 15.4° F; Shaunavon, Sask. (near Monchy), 66.7° F and 11.6° F. In the southern part of the region winter Chinook winds that bring mild Pacific air often cause extremely rapid rises of 40° F to 50° F in temperature in a few hours and cause diurnal ranges of 60° F to 80° F. Near Lethbridge in southern Alberta such winds can bring temperatures of 40° F or higher in one day of three during the winter. All along the route high temperatures in excess of 80° F and lows below -40° F are not uncommon. The mean number of days with daily temperature below freezing ranges from more than 250 at the Beaufort Sea to 200 at 60° N. latitude, but many hours of summer sunlight compensate in part for the short growing season. Near the Canada-U.S. border mean daily temperatures below freezing occur from November to March and spot readings below 32° F have been recorded in nearly all months.

Precipitation

Along most of the proposed pipeline route total precipitation varies from less than 10 inches at the Beaufort Sea coast to somewhat less than 24 inches in central and southwestern Alberta. Fernie, B.C., which is atypical because of local topographic features, receives mean annual precipitation of 41.46 inches, largely in the form of snow (143.2 inches). Throughout the rest of the region traversed by the proposed pipeline route most precipitation is in the form of summer rain. In Alberta, particularly, most storms are thunder showers. North of 60° N. latitude, except near the head of the Mackenzie Delta where it is nearly 7 1/2 feet, mean annual snowfall is not much more than 5 feet, with the heaviest mean monthly snowfall usually in October. In the plains parts of Alberta and Saskatchewan annual snowfall is commonly less than 3 1/2 feet. In the mountains and foothills in Alberta and British Columbia orographic features cause local variations, as at Fernie, B.C.; in general annual snowfall is 5 to 8 feet.

Wind

Mean hourly winds decrease from about 12 to 15 miles per hour (mph) at the Beaufort Sea coast to 6 to 8 mph in the southern part of the Mackenzie Valley. Extreme winds may be 5 or more times as high and are most common in winter. Also in winter, there may be long periods (several days) of calm. If the temperature is low enough (-22° F) during a calm period, a temperature inversion exists, and if a source of moisture such as a steaming herd of caribou or exhaust gases from internal combustion engines is present, ice fog may form. The fog flows downhill and collects in topographically low areas. South of 60° N. latitude much of the area near the proposed pipeline route is characterized by winds, largely from the west, generally below 10 mph, but with frequent storms with gusts well above 60 mph. In southwestern Alberta and southeastern British Columbia the effects of local topographic features may cause large variations from regional norms, giving rise to frequent calm spells in both winter and summer. If low temperatures and even moderate winds occur at the same time the resulting "chill factor" may seriously restrict or even make impossible human outdoor activity.

2.1.2.2 Topography

This description of topographic and geographic features along the route of the proposed pipeline in Canada is based on examination of Alignment Sheets provided by Canadian Arctic Gas Pipeline, Ltd. (CAGPL, 1974f,g; 1975a, section 8.a.3) and on examination of 1:250,000-scale topographic maps (Canada Dept. of Energy, Mines, and Resources).

Following a general summary, the proposed route is discussed in terms of the five major parts into which it has been divided: 1) the Prudhoe Bay Supply Line (extending from Alaska), and 2) the Richards Island Supply Line (together with its branch, the Parsons Lake Lateral) in the north; 3) the Main Line, divided for convenience intc two parts, that in Northwest Territories (north of 60° N latitude) and that in Alberta (south of 60° N latitude); and 4) the Monchy Delivery Line and 5) the Kingsgate Delivery Line in the south, which would distribute the gas respectively to the eastern and western parts of the conterminous United States.

Slopes along each major part of the proposed route are generally discussed first. They were determined in an approximate fashion by examination of the profiles on the Alignment Sheets. The words used here to describe the slopes may not necessarily connote the same values used by others, so that caution is needed in equating these terms with similar terms used by others, although a rough correlation between the terms used here and in other places is expectable. As used here, the slope terms have the approximate values shown in Table 2.1.2.2-1.

Slopes transverse to the route of the proposed pipeline are not discussed because this information is generally not apparent on the Alignment Sheets, and the topography shown on the 1:250,000-scale topographic maps is not adequate for a proper evaluation. General elevation (in hundreds of feet above sea level) is discussed for each part, as are maximum and minimum elevations (to about the nearest 5 feet). A range of local relief, the difference between high and low points along the profile over a span of roughly half a mile, is also given (usually in terms of 25 or 50 feet). All elevation figures are based on the values in the route profiles on the Alignment Sheets.

Two page-size maps covering the entire proposed route (Figures 2.1.2.2-1 and -2) accompany the summary in the next section. These maps also serve as the index for a series of topographic maps (Figures 2.1.2.2-3 to -31)

Table 2.1.2.2-1 Quantitative equivalents of descriptive slope terms

Descriptive term	Percent	Degrees (approximate)
Nearly flat	Less than 1	Less than ½
Very gentle	1 - 2	½ - 1
Gentle	2 - 5	1 - 3
Moderate	5 - 10	3 - 6
Moderately steep	10 - 25	6 - 14
Steep	25 - 70	14 - 35
Very steep	More than 70	More than 35

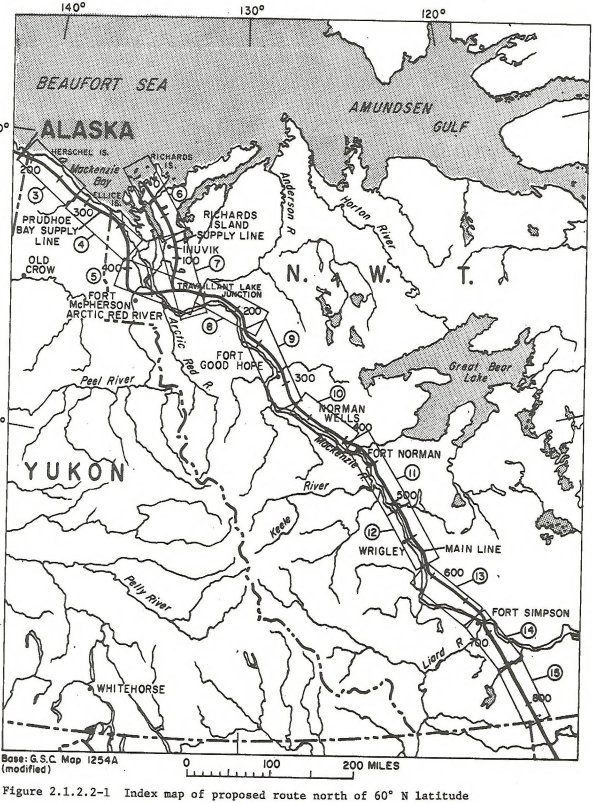


Figure 2.1.2.2-1 Index map of proposed route north of 60° N latitude

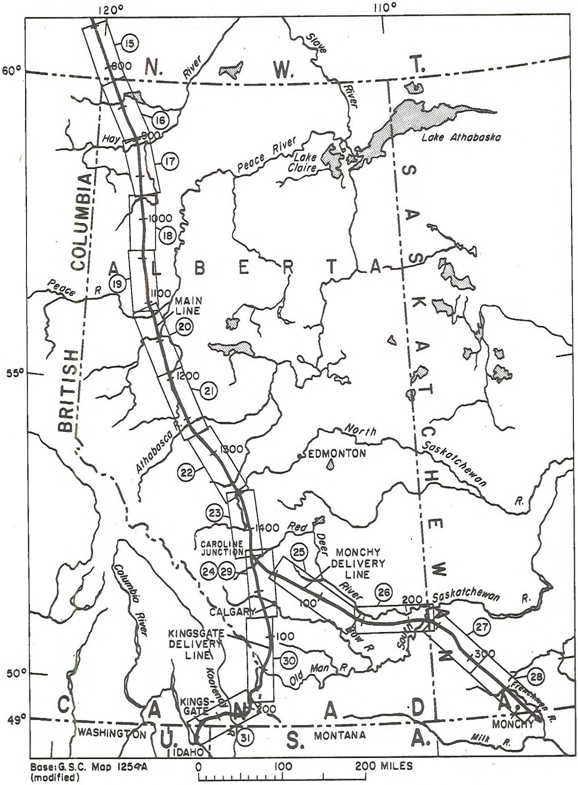


Figure 2.1.2.2-2 Index map of proposed route south of 60° N latitude

that are based on the Canada National Topographic Series, scale 1:250,000. These maps appear at the end of this volume. They show the place names mentioned throughout this Statement, and illustrate the relationship of the route to the surroundings. The position of the route on the maps, and each 10th milepost along the route, were determined from the Alignment Sheets. The topographic detail of the maps is not sufficient, however, to portray, except in a very general way, the slope and elevation information contained in the route description and derived from the Alignment Sheets.

Summary Description of Route

Location

The Canadian part of the route of the proposed pipeline extends for about 2,435 miles in a generally southeasterly direction across western Canada from two points near the Beaufort Sea (part of the Arctic Ocean) to two points on the Canada-U.S. border along 49° N. latitude. The route thus includes a single Main Line with two branches at each end, as previously described (Figures 2.1.2.2-1 and 2).

The Prudhoe Bay Supply Line is a continuation of the proposed line from Prudhoe Bay in Alaska. It continues in Canada for about 297 miles, from the Alaska-Yukon border, across the northern part of Yukon Territory near the Beaufort Sea (Arctic Ocean), and into the Northwest Territories, crossing the Mackenzie River and terminating at Travaillant Lake Junction. At this point it is joined by the proposed Richards Island Supply Line, which runs for about 143 miles south from near the Arctic Ocean, parallel to the Mackenzie River; this line has a 15-mile branch, the Parsons Lake Lateral Line.

The proposed Main Line extends for about 1,305 miles southeastward from Travaillant Lake Junction to Caroline Junction in the Province of Alberta. It follows the valley of the Mackenzie River for more than 500 miles, then crosses a series of major tributaries to the Mackenzie River before passing into Hudson Bay drainage, about 80 miles from the southern end.

At Caroline Junction the proposed route splits into two delivery lines. The Monchy Delivery Line continues southeastwardly for about 394 miles across southern Alberta and southwestern Saskatchewan to the U. S. border, where it joins the proposed Northern Border route to the eastern United States. The Kingsgate Delivery Line runs southward and southwestward from Caroline Junction for about 281 miles across the Rocky Mountains to the British Columbia-Idaho border, where it is proposed to continue by two routes to the west coast of the United States.

Drainage Basins

The pipeline route in Canada crosses drainage basins that drain to all three of the oceans that border North America: the Arctic Ocean on the north, the Atlantic Ocean on the east, and the Pacific Ocean on the west.

The two Supply Lines and most of the Main Line lie within basins that drain northward into the Arctic Ocean. The western part of the Prudhoe Bay Supply Line crosses numerous small individual basins. The remainder of this part of the route lies within the very large basin of the Mackenzie River, including its major upper basin tributaries that reach the Mackenzie by way of Great Slave Lake, Lake Athabasca, and the Slave River which joins the two large lakes.

The southernmost 83 miles of the Main Line, most of the Monchy Delivery Line, and about the northern two-thirds of the Kingsgate Delivery Line lie within the drainage basin of the Saskatchewan River which drains northeastward into Hudson Bay, a large arm of the Atlantic Ocean. The southeasternmost end of the Monchy Delivery Line is also in Atlantic drainage, but this drainage is southeastward into the Mississippi River and the Gulf of Mexico.

The southern third of the Kingsgate Delivery Line lies within the upper part of the Columbia River drainage system, which drains generally, but tortuously, westward to the Pacific Ocean.

Slopes

The topography along all of the proposed route except the Kingsgate Delivery Line is dominated by slopes that are nearly flat to very gentle. The Richards Island Supply Line and the northern part of the Main Line have many stretches of moderate to gentle slope interspersed between the nearly flat areas. For much of the Prudhoe Bay Supply Line, the remainder of the Main Line, and the Monchy Delivery Line, the lengths that depart from nearly flat slope have slopes that are dominantly very gentle, with fewer areas of moderate slope. Throughout these routes, however, there are numerous short stretches, ranging from a few hundred feet to about half a mile in length, where there are moderately steep to very steep slopes. These occur mainly at river crossings, and range from less than 25 to as much as 600 feet high. The slopes at these river crossings form the main topographic barriers along the route.

Most of the proposed Kingsgate Delivery Line lies in a different topographic setting as it crosses the Rocky Mountains and related ranges of the Cordilleran region. Slopes here are dominantly moderate to steep for much more of this route than for the other routes. Long steep slopes over 1,000 feet high occur in several places, as do shorter, very steep slopes. Gentle to very gentle slopes are common along river valleys, but nearly flat slopes are limited to relatively short stretches.

Elevations

The two northern branches of the proposed route are generally lowest in elevation, lying near sea level in a few places but commonly running at elevations lower than 500 feet above sea level, terminating at their common high point, about 800 feet.

In the Mackenzie Valley, the proposed Main Line remains below 1,000 feet most of the way, falling to below 100 feet in a few places but generally lying 300 to 800 feet above sea level and a few hundred feet above the nearby river level. After leaving the Mackenzie Valley, the route climbs gradually to about 2,000 feet near the Northwest Territories-Alberta border, and to over 4,000 feet at its highest point in central Alberta. The elevation drops to nearly 1,000 feet at the Peace River but generally lies between 2,000 and 4,000 feet through central Alberta. This same range of elevation obtains throughout the Monchy Delivery Line, though it barely drops below 2,000 feet at its low point, crossing the South Saskatchewan River.

The Kingsgate Delivery Line, starting just below 4,000 feet, climbs to over 6,000 feet in several places, reaching about 7,000 feet, the highest point on the whole system in Canada, crossing Flathead Ridge. The lowest point on the Kingsgate Delivery Line is about 2,400 feet, at the Kootenay

River, but in general the elevation of this part of the route lies between 4,000 and 5,000 feet.

Relief

Local relief along much of the proposed route in the nearly flat areas is negligible, but where there is hummocky or hilly terrain, local relief generally ranges between 50 and 100 feet. Stream crossings provide most of the relief along the route, and at these places it ranges from 25 to 50 feet for smaller streams, from 100 to 200 feet for most rivers, and from 300 to 600 feet at the largest rivers.

On the proposed Kingsgate Delivery Line local relief of 100 to 500 feet is not uncommon, and at the major ridges in the mountains it is as much as 1,000 feet. The route naturally is chosen to minimize relief along its profile, and in much of the mountainous terrain the general relief transverse to the route is on the order of 2,000 to 3,000 feet.

Relief measured over longer distances, such as the several miles between one major stream crossing and the divide to the next drainage basin, is commonly 200 to 500 feet for most of the proposed route, but a few thousand feet on the Kingsgate Delivery Line.

Route Description

Prudhoe Bay Supply Line

The proposed Prudhoe Bay Supply Line is shown on Figures 2.1.2.2-3 through -5. It enters Canada at the Alaska-Yukon border, at pipeline Milepost 195, and ends at the junction with the proposed Richards Island Supply Line at Travaillant Lake Junction, Milepost 492 of this route, extending over a distance of 297 miles. The part of this route in Canada can be divided into three segments, on the basis of groups of drainage basins traversed. In the first segment, for 127 miles, the route crosses numerous rivers and streams that drain directly into the Arctic Ocean; in the second, for 108 miles, it crosses small streams that drain into the western side of the Mackenzie River delta; and in the third, for about 62 miles, it crosses the valley of the Mackenzie River.

For much of this proposed route, the ground is nearly flat; intervening areas have slopes that range from very gentle to moderate. Moderately steep to steep slopes occur principally at stream crossings. The general elevation of much of the route is between 200 and 300 feet, but in the area west of the Mackenzie River delta this level rises to 600 feet, and at the end of the route the general elevation reaches 800 feet. Smaller parts of the route lie between sea level and 100 feet. The minimum elevation is near sea level at the crossing of the Mackenzie River, and the maximum is 830 feet at Travaillant Lake Junction. Local relief is generaly between 50 and 100 feet but in places is as much as 250 feet. For some stretches, it rarely exceeds 50 feet and commonly is less than 25 feet.

Richards Island Supply Line

The proposed Richards Island Supply Line is shown on Figures 2.1.2.2-6 and -7. It begins at Milepost 0, near Big Lake, about 7 miles from Mackenzie Bay, and trends generally southward to southeastward across Richards Island and over the North Storm Hills. It terminates at Travaillant Lake Junction, just beyond Milepost 143, where it meets the

Prudhoe Bay Supply Line to form the Main Line of the proposed pipeline route. This line is divided into three segments. The first comprises the crossing of Richards Island, which has numerous lakes and small streams that are part of or tributary to the Mackenzie River delta distribution system. In the second segment, the route traverses the North Storm Hills, crossing small streams and lakes that drain either to the Mackenzie River itself or to the Eskimo Lakes part of the Mackenzie River delta. In the last segment, the route crosses the drainage of the Rengleng River, a larger tributary to the Mackenzie.

For parts of this route, slopes are nearly flat, but in other places moderate to gentle slopes dominate as the route traverses more hilly country. Moderately steep to steep slopes occur only in small areas near stream crossings and on the sides of a few of the higher hills. The general elevation is less than 100 feet in the northern part but in the North Storm Hills reaches 300 to 500 feet and in the southern part of the route is 500 to 800 feet. The minimum elevation is near sea level at the Mackenzie River, and the high point is 830 feet at Travaillant Lake Junction. Local relief is commonly between 50 and 100 feet, with some stretches of relief of less than 50 feet and other places where it is as much as 300 feet.

A separate proposed route segment, the Parsons Lake Lateral Line, is also included here. It is about 15 miles long and is a feeder line to the Richards Island Supply Line.

On the Parsons Lake Lateral Line slopes are generally gentle to moderate, with some areas of steep slope as much as 100 feet high and other small areas that are nearly flat. The general elevation is on the order of 200 to 400 feet, with local relief of about 100 feet. The highest elevation is about 500 feet, at Milepost 13, and the low point is about 115 feet, near Milepost 5.

Main Line, Travaillant Lake Junction to Alberta Border

The Main Line of the proposed pipeline route in Northwest Territories is shown on Figures 2.1.2.2-7 through -15. It begins at Travaillant Lake Junction, Milepost 126 (there are no lower numbers in this numbering sequence), and reaches Milepost 821 near the N.W.T.-Alberta border (Figure 2.1.2.2-1); it is about 695 miles long. This part of the route lies entirely within the drainage basin of the Mackenzie River, which drains northward and northwestward into the Arctic Ocean. As far as Milepost 583, this part of the route parallels the Mackenzie River on its east side, crossing numerous tributaries to the Mackenzie at more or less right angles. For the next 100 miles the route lies to the northeast of the Mackenzie, crossing it at Milepost 683. The route then continues generally south-southeastward, crossing the drainage basins of tributaries to the Mackenzie, including those of the Liard River, Jean-Marie Creek, Trout River, and Kakisa River; the Alberta border is crossed within the last-named basin.

For most of this part of the route there are segments of nearly flat slopes alternating with segments of gentle to moderate slopes; these segments range from about 5 to 20 miles in length. Moderately steep to steep slopes occur in only scattered places, principally at stream crossings, and on the southeast flank of the Ebbutt Hills.

Along the Mackenzie River the elevation of the route generally ranges between 300 and 800 feet, lying several hundred feet above the river in most places. The route climbs to its highest point, 2,230 feet, east of the Mackenzie River in the Ebbutt Hills, near Milepost 640. The lowest point is 65 feet, at the crossing of the Hare Indian River. Local relief along the profile of the route is commonly 100 feet or more in the northern part, but this decreases to less than 50 feet to the south. Relief is usually higher at stream crossings, and is as much as 1,000 feet on the southeast side of the Ebbutt Hills.

South of the Mackenzie River crossing, the route climbs from about 620 feet to a maximum of 2,480 feet at the divide between the Trout and Kakisa Rivers. Local relief in this area is commonly negligible but as much as 100 feet in some places.

Main Line, Alberta Border to Caroline Junction

The Main Line of the proposed pipeline route in the Province of Alberta is shown on Figures 2.1.2.2-16 through -24. It enters Alberta at about Milepost 821, and continues for about 610 miles southeastward to southward across the Province to the terminus at Caroline Junction, about Milepost 1430 (actually 1429.56), where it splits into the Monchy and Kingsgate Delivery Lines (Figure 2.1.2.2-2). Because of a change in the proposed alinement between about Mileposts 583 and 865 (Figures 2.1.2.2-13 through -16), there is a duplication of milepost designations between Mileposts 863.4 and 864.8, where the new alinement rejoins the previous alinement. Thus the segment between Mileposts 860 and 870 (Figure 2.1.2.2-16) is actually 11.4 miles long. This part of the route is divided into 12 segments, on the basis of drainage basins crossed. The first 10 of these drain northward into the Arctic Ocean via the Mackenzie River, and include the basins of the Kakisa River (which drains directly into the Mackenzie), the Petitot River (which drains into the Liard River), the Hay River (which drains into Great Slave Lake and thence into the Mackenzie River), the Chinchaga River, a tributary to the Hay River, five basins that drain into the Peace River (which drains into the Slave River and thence into Great Slave Lake), and the Athabasca River basin (which drains into Lake Athabasca and thence into the Slave River). The remaining two basins are those of the North Saskatchewan and the South Saskatchewan Rivers, which drain into Hudson Bay via Lake Winnipeg and the Nelson River.

Slopes are nearly flat to very gentle for much of this part of the route, but in several areas there are dominantly moderate to gentle slopes in hilly areas, with steep slopes common at the crossings of the major rivers, principally those named above. The elevation generally rises southward from about 2,000 feet in the north to 3,500 to 4,000 feet in the south; the minimum elevation is 1,035 feet at the crossing of the Peace River, and the maximum elevation is 4,120 feet at the divide between the Athabasca River and its tributary, the McLeod River. Except for the Kingsgate Delivery Line, which crosses the Rocky Mountains, this divide is the highest point on the entire proposed pipeline system in Canada. Local relief is negligible in the nearly flat areas, but commonly 50 to 200 feet in the hilly areas, and up to 600 feet at river crossings; this maximum figure occurs at the Peace River.

At Milepost 922 the proposed route joins the route of a gas pipeline of the Alberta Gas Trunk Line Ltd. This line and the proposed pipeline follow generally the same alignment from Milepost 922 to approximately Caroline Junction, Milepost 1430. A dashed-line pattern is shown adjacent to the proposed pipeline on Figures 2.1.2.2-17 through -24 where the proposed line would be within 500 feet of the existing pipeline.

Monchy Delivery Line

The Monchy Delivery Line part of the proposed pipeline route is shown on Figures 2.1.2.2-24 through -28. It begins at Caroline Junction, Mile 0, in Alberta, and runs generally southeastward and eastward across southern Alberta and the southwest corner of Saskatchewan to the Canada-U.S. border at Milepost 394, east of the town of Monchy (see Figure 2.1.2.2-2). Most of this route lies within the drainage of the South Saskatchewan River, which drains ultimately into Hudson Bay, but the last 50 miles or so drains south to the Gulf of Mexico via the Missouri and Mississippi Rivers. However, within and between each of the drainage basins crossed there are extensive areas in which drainage does not enter any of the major river systems to reach the oceans but which instead drains to various lakes that occupy closed depressions at the low points of their respective drainage areas. Most of these internal systems are quite small, but that of the Notukeu River extends for about 100 miles into central Saskatchewan. The external drainage basins crossed that drain into the South Saskatchewan River are those of the Red Deer River and its tributaries, Rosebud River and Matzhiwin Creek, that of the South Saskatchewan River itself, and that of Swiftcurrent Creek. The Missouri River basins are those of the Frenchman River and the Milk River, the former of which drains first into the latter.

Slopes along most of this route are nearly flat to very gentle, but there are several areas of moderate to gentle slopes, with some steep slopes where the route crosses sand hills; stream crossings commonly are bordered by short distances of steep to very steep slopes. The elevations generally range between 3,500 and 2,400 feet, the highest elevations being about 3,800 feet at the beginning of the line, and the lowest about 1,900 feet at the South Saskatchewan River. Overall relief within each drainage basin is about 500 feet, with local relief commonly less than 50 feet except at stream crossings, where it is as much as 400 feet.

In the first 220 miles south of Caroline Junction the proposed Monchy Delivery Line would closely parallel an existing pipeline of Alberta Gas Transmission Ltd. Segments in which the existing line is within about 500 feet of the proposed pipeline are shown by a dashed-line pattern on Figures 2.1.2.2-24 to -26.

Kingsgate Delivery Line

The route of the proposed Kingsgate Delivery Line is shown on Figures 2.1.2.2-29 through -31. It begins at Caroline Junction in Alberta, Milepost 0, and extends southward and southwestward into British Columbia, ending at the Canada-U.S. border at Milepost 281 (Figure 2.1.2.2-2). The route may be divided into 13 segments, on the basis of drainage basins crossed; the first nine of these, in Alberta, drain eastward into Hudson Bay via the South Saskatchewan River; the remaining four, in British Columbia, drain ultimately westward into the Pacific Ocean via the Columbia River. The South Saskatchewan drainage basins comprise that of the Red Deer River, those of the Bow River and four of its tributaries, Elbow River, Fish Creek, Sheep River, and Highwood River, and those of the Oldman River and two of its tributaries, Willow Creek and Crowsnest River. Three of the four Columbia drainage basins are part of the Kootenay River system, namely, those of Michel Creek, the Kootenay River itself, and the Moyie River. The fourth is the Flathead River basin, the drainage of which reaches the Columbia River by a long detour through Montana and Idaho by way of Clark Fork and the Pend Oreille River.

The Kingsgate Delivery Line route crosses the most rugged topography of the entire proposed pipeline system, and in many segments slopes are dominantly steep to moderate, with numerous long stretches of very steep slopes; only in a few valleys are the slopes gentle to very gentle, and rarely nearly flat. Except near the International Boundary, where they are lower, elevations generally range between 4,000 and 5,000 feet, reaching over 6,000 feet in several places, the highest point, about 7,000 feet at Flathead Ridge, being the maximum elevation on the entire proposed system; the lowest point on the route of the proposed Kingsgate Delivery Line is about 2,300 feet at the crossing of the Kootenay River. An impoundment of the Kooteway River by Libby Dam may extend upstream of this crossing. Local relief generally ranges between 100 and 500 feet, and is up to 1,000 feet in places, while the general relief of the surrounding terrain is 2,000 to 3,000 feet in the mountainous areas.

For most of the proposed Kingsgate Delivery Line the route would parallel existing pipelines of Alberta Gas Transmission Ltd., Alberta Natural Gas Co., Hudson Bay Oil and Gas Ltd., or Saratoga Processing Co. Ltd. The route alignment maps (Figures 2.1.2.2-29 to 2.1.2.2-31) show a dashed-line pattern for places where these pipelines would be within 500 feet of the proposed pipeline.

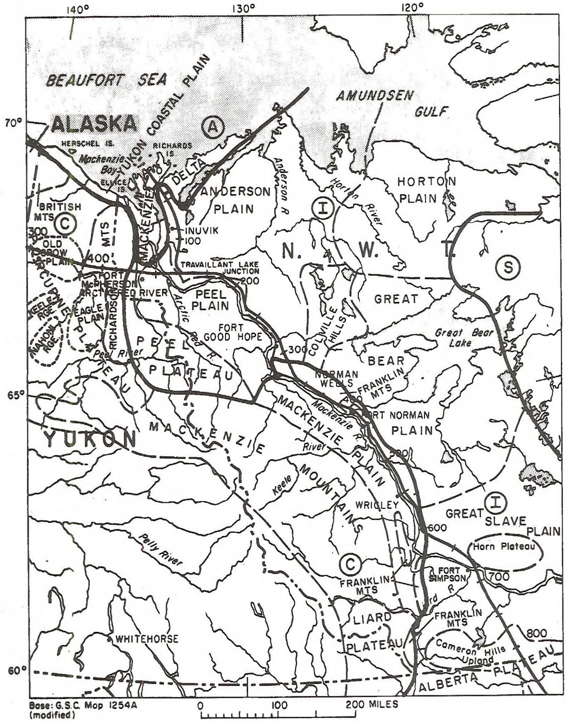
2.1.2.3 Geology

This section of the Environmental Impact Statement describes the present geologic conditions along the proposed route chosen by the Applicant and discusses the geologic processes operative there, both at present and during the recent geologic past.

This discussion of the geology of the proposed route is the result of office studies by many different geologists. The descriptions that follow are necessarily generalized and are suitable for purposes of overall evaluation rather than for detailed studies of specific sites.

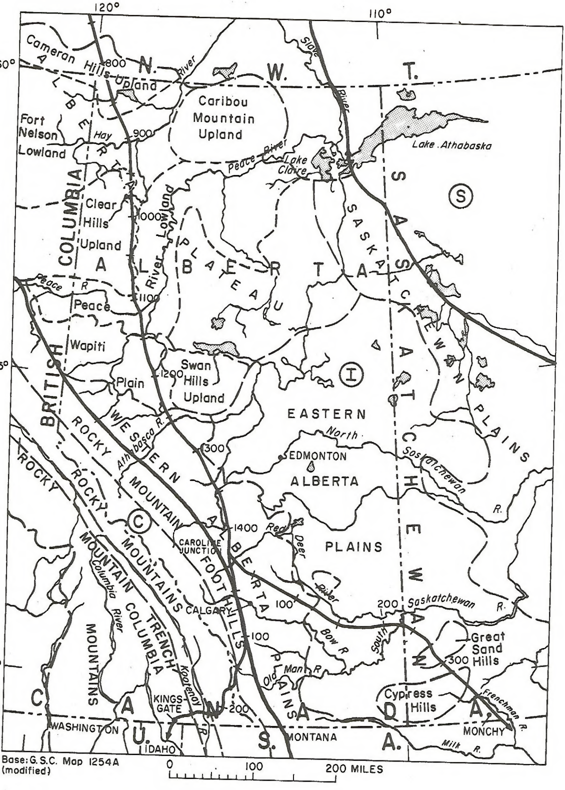
Physiography

Canada is divided physiographically and geologically into two broad groupings of physiographic regions, those comprising the Canadian Shield, consisting dominantly of Precambrian crystalline rocks and generally surrounding Hudson Bay, and those comprising the Borderlands, composed dominantly of younger stratified rocks surrounding the shield. The route of the proposed gas pipeline lies entirely within the Borderlands, and mostly within the Interior Plains Region of the Borderlands. The northern ends of both the proposed Prudhoe Bay Supply Line and the proposed Richards Island Supply Line lie within the Arctic Coastal Plains Region. Parts of the proposed Main Line and most of the proposed Kingsgate Delivery Line lie within the Cordilleran Region. The relationship of the proposed route to these regions, and to the physiographic provinces into which they are divided, is shown on Figures 2.1.2.3-1 and -2. The physiographic scheme used in this section is based mostly on the work of Bostock (1970), but additional details have been gleaned from the Atlas of Alberta (Government of Alberta, 1969), and the Atlas of Saskatchewan (Richards and Fung, 1969). The placement of the proposed route within the various provinces and subprovinces and further descriptions of the terrain traversed are based on examination of the route as plotted on the topographic maps (Figures 2.1.2.2-3 to -31 in the back of this volume.



Base: G.S.C. Map 1254A (modified)

Figure 2.1.2.3-1 Selected physiographic provinces and subprovinces north of 60° N latitude



Base: G.S.C. Map 1254A (modified)

Figure 2.1.2.3-2 Selected physiographic provinces and subprovinces south of 60° N latitude

Description of Physiographic Regions

Interior Plains Region

The Interior Plains Region extends in a long southeast-trending belt across Canada from Amundsen Gulf, an arm of the Beaufort Sea (Arctic Ocean), to the U.S.-Canada border at 49° N. latitude, where it continues into the United States. The region is bordered on the west by the mountainous Cordilleran Region, and on the east largely by the Canadian Shield. The Interior Plains are underlain generally by nearly flat-lying Mesozoic, Paleozoic, and Tertiary sedimentary rocks, dominantly shale and sandstone. In many places bedrock is covered by glacial deposits, chiefly from the last glaciation. In some places these relatively soft deposits are thin, and in many steep valley sides the bedrock is exposed. In a gross sense, the plains contain dominantly smooth topography, with a surface that is generally higher in elevation adjacent to the mountains on the west, and lower to the east and north. In detail, however, there is a variation in character of the land surface, so that the region is divided into provinces, some of which, referred to as hills or plateaus, are of higher relief and more irregular surface, whereas others are called plains or lowlands and are of lower relief and have the smoother topography characteristic of the region as a whole. Even within the plains and lowlands, however, there are smaller areas of hilly character. Throughout the Interior Plains, the rivers and streams are incised beneath the general land surface, either in narrow steep-sided valleys or in more gently sloping broad lowland areas. These valley sides are the places of greatest relief within the Interior Plains, form the greatest surface barriers to transportation of all kinds, and constitute many of the problem areas in pipeline construction.

Arctic Coastal Plains Region

The Arctic Coastal Plains Region, in general, forms a relatively narrow border adjacent to the Beaufort Sea (Arctic Ocean), and in the area of concern is divided into two provinces--the Yukon Coastal Plain and the Mackenzie Delta. Like the Interior Plains, these are areas of relatively smooth topography. The surface slopes generally toward the ocean. In many places, however, this surface is hummocky, because of the presence of glacial moraine deposits (in the Yukon Coastal Plain), or pingos (in the older parts of the Mackenzie Delta), or because it is made irregular by the presence of numerous lakes and distributary streams (as on the younger part of the delta). Bedrock underlying the Yukon Coastal Plain is largely concealed by relatively young deposits of marine and/or glacial origin, and, particularly in the western part, by alluvium. The Mackenzie Delta, on the other hand, is composed primarily of fine-grained deposits of the fluvial-marine interface.

Cordilleran Region

The Cordilleran Region comprises all of the mountains and intermontane lowlands of western Canada, stretching from the Alaska-Yukon border to 49° N. latitude generally parallel and adjacent to the Interior Plains Region. In gross outline, the Cordilleran Region can be divided into an eastern part dominated by the Rocky Mountains and related ranges, and consisting primarily of folded sedimentary rocks; a central part of less mountainous character that includes both folded sedimentary rocks and metamorphic-igneous complexes; and a western part composed primarily of the Coast Ranges of chiefly plutonic igneous rocks. The mountainous terrain is characterized by steep slopes with thousands of feet of relief; less rugged land is confined to narrow valleys that connect with each other in branching fashion but rarely form a continuous path across the mountains. There are, however, relatively low parts of the mountains where the barrier effect is minimized though not eliminated, and such areas serve as the major transportation routes. The plateaus in the central part of the Cordilleran Region have large areas of relatively smooth topography but are broken up by incised valleys with relief as great as or greater than that of the higher parts of the Interior Plains.

Description of the Proposed Route North of 60° N. Latitude

The route of the proposed pipeline in Canada is described below in terms of the physiographic provinces and subprovinces that it traverses. This section considers those parts of the route in Yukon Territory and the Northwest Territories, north of 60° N. latitude, and the following section considers those parts of the route in Alberta, Saskatchewan, and British Columbia, south of 60° N. latitude.

The northern part of the proposed route consists of three parts, the Prudhoe Bay Supply Line, the Richards Island Supply Line (with its branch, the Parsons Lake Lateral Line), and the northern part of the Main Line. The three lines intersect at Travaillant Lake Junction. These lines, and the physiographic provinces they traverse, are illustrated in Figure 2.1.2.3-1.

Prudhoe Bay Supply Line

This segment of the proposed route traverses the Yukon Coastal Plain, follows the edge of the Richardson Mountains adjacent to the Mackenzie Delta, crosses the northern end of the Peel Plain, and ends at Travaillant Lake Junction on the southwest edge of the Anderson Plain.

Yukon Coastal Plain--The proposed route runs the length of this narrow province, generally near its inner, upslope, southwestern edge, between the Alaska-Yukon border at Milepost 195 (Figure 2.1.2.2-3) and about Milepost 340 (Figure 2.1.2.2-4). For the first 30 miles, the British Mountains lie to the south of the Coastal Plain, which is veneered by a complex of alluvial fans and channel and terrace alluvium of major streams that emerge from the mountains and flow to the Beaufort Sea. These alluvial surfaces slope gently from the mountain front to the ocean, and are broken only where the streams are incised beneath the general level. Between Milepost 225 and the Spring River near Milepost 255, where the Buckland Hills lie between the Coastal Plain and the British Mountains (Figure 2.1.2.2-3), the veneer of alluvium is not as continuous or as well developed; the surface is dominated by slightly hummocky terrain composed of glacial deposits. Most of the plain in this sector, as well as the next part as far as the Blow River at Milepost 307, is lake covered with an irregular surface. By staying near the southwestern edge of the plain, the proposed route avoids most of the lakes. East of the Blow River the Coastal Plain becomes narrower and pinches out at about Milepost 340. The Richardson Mountains lie to the south, and the Mackenzie Delta to the north.

Richardson Mountains--Between Milepost 340 (Figure 2.1.2.2-4), where the Yukon Coastal Plain ends, and about Milepost 410 (Figure 2.1.2.2-5), the proposed route is technically in the Richardson Mountains which have rugged peaks up to 5,500 feet in elevation developed in Paleozoic and Mesozoic sedimentary rocks, actually however, the route skirts the mountains and runs along a belt of moraines deposited by a glacier which came down the Mackenzie Valley and abutted the mountains. The glacial deposits are thin and bedrock is at shallow depth in many places. South of Milepost 376 (Figure 2.1.2.2-4) the route drops from the moraines onto a belt of small coalescing alluvial fans formed by streams which emerge from the mountains, cross the morainal belt, and deposit the fans as they empty into the adjacent Mackenzie Delta.

Peel Plain--At about Milepost 410 the proposed route leaves the Richardson Mountains and crosses the extreme northern end of the Peel Plain, as far as about Milepost 488 (Figure 2.1.2.2-5). The Peel Plain here is a surface of low relief made up of gently hummocky moraine interspersed with stream and colluvial deposits. East of the Mackenzie River, crossed near Milepost 457 (Figure 2.1.2.2-5), the plain is very densely lake dotted, and the route wends its way between lakes on hummocky morainal ground.

Anderson Plain--For the last few miles between Milepost 488 and Travaillant Lake Junction at Milepost 492 (Figure 2.1.2.2-5), the proposed route ascends the southwestern edge of the Anderson Plain, which is described in the following section on the proposed Richards Island Supply Line.

Richards Island Supply Line

This proposed route segment begins in the Mackenzie Delta and crosses the west edge of the Anderson Plain, ending at Travaillant Lake Junction, Milepost 143 (Figures 2.1.2.2-6 and -7).

Mackenzie Delta--The Mackenzie River ends in a large complex delta that extends along about the last 120 miles of the river and is about 250 miles wide along the Arctic Ocean. The delta consists of an older part, largely in the northeast, and a younger part, generally to the west along the present river. The older part is generally more hummocky because of the pingos developed on it, and contains numberous lakes. The younger part contains a maze of lakes and distributary streams as well as the three main channels of the river. The proposed route traverses the Mackenzie Delta for the first 34 miles (Figure 2.1.2.2-6). It is located on Richards Island, a large complex island between two of the main channels of the Mackenzie River. It begins near Big Lake in the younger part of the delta, and continues across the central part of this island which contains an older part of the delta and which has a more irregular surface. Throughout this province the proposed route threads its way between the maze of lakes.

Anderson Plain--This is the most northerly of the Interior Plains provinces. Its surface reaches sea level at its northern edge along Liverpool Bay and Amundsen Gulf. This surface generally slopes upward to the south, reaching elevations of 800 to 1,000 feet in the southern part. The terrain to the south is also more irregular, with the channels of present and former streams, some lake filled, 200 to 300 feet below the general surface. There are some bedrock outcrops in this higher part of the plain, but generally the surface is underlain by glacial deposits. The proposed route enters the Anderson Plain at about Milepost 32 (Figure 2.1.2.2-6) and continues across the plain to the terminus at Travaillant Lake Junction. The proposed Parsons Lake Lateral, about 15 miles long, lies entirely within the Anderson Plain. Main Line, Travaillant Lake Junction to N.W.T.-Alberta Border

Between Travaillant Lake Junction and the N.W.T.-Alberta border (Figures 2.1.2.2-7 through -15), the Main Line of the proposed route continues across the southwestern edge of the Anderson Plain, dropping off in places to the adjacent Peel Plain; traverses the length of the Franklin Mountains (including both the Norman Range and the McConnell Range), leaving them in places to cross small parts of the adjacent Mackenzie Plain; crosses the westernmost part of the Great Slave Plain; and then enters the Cameron Hills Upland, the most northerly part of the complex Alberta Plateau.

Anderson Plain and Peel Plain--The southwestern part of the Anderson Plain--that traversed by the proposed route--is its highest, most rugged part. Between Travaillant Lake Junction (Milepost 126) and about Milepost 155 (Figure 2.1.2.2-8) the route crosses a typical, generally hummocky, and lake-dotted segment of the Anderson Plain. For about 20 miles from about Milepost 155 the route runs through an area that comprises a zone of transition between the Anderson Plain and the adjacent lower and less irregularly surfaced Peel Plain. At about Milepost 187 (Figure 2.1.2.2-8) the route is definitely on the edge of the Peel Plain; there is a well-defined escarpment about 500 to 900 feet high just to the northeast of the proposed route that clearly separates the two provinces. In this sector the route is within a few miles of the Mackenzie River, which is incised a few hundred feet below the surface of the Peel Plain, in most places bounded by a steep bluff. At Milepost 220 (Figure 2.1.2.2-8) the proposed route climbs the boundary escarpment and once again is on the surface of the Anderson Plain. From here to about Milepost 266 (Figure 2.1.2.2-9) it traverses this surface, which is somewhat smoother than that near Travaillant Lake, but is interrupted in places by streams that are incised beneath its surface as they approach the Mackenzie River. This sector culminates in the Ramparts Plateau near Milepost 260. From about Milepost 266 to the end of the Anderson Plain, at about Milepost 316 near Chick Lake (Figure 2.1.2.2-9), the proposed route traverses a transition zone with no clearly defined border between the Anderson Plain and the Peel Plain. In this transition zone, relief is lower and the topography generally smoother than in the more typical higher parts of the Anderson Plain, and more nearly resembles that of the Peel Plain.

Franklin Mountains-Norman Range--The Franklin Mountains comprise a series of relatively low linear ridges that form the northeasternmost part of the Eastern System of the Cordilleran Region. They are separated from the main body of the Eastern System, here called the Mackenzie Mountains, by the Mackenzie Plain, the lowland at the eastern side of which the Mackenzie River flows. The Franklin Mountains are composed of Paleozoic carbonate rocks, and have been overridden by glacier ice from the east. The Norman Range is part of the northwesterly sector of the Franklin Mountains and parallels the Mackenzie River for more than 100 miles. The range is composed of several ridges arranged in crudely en echelon fashion, with gaps, generally occupied by rivers, between them. The Norman Range reaches elevations of over 3,000 feet, but the more northerly ridges are lower. The proposed route first passes along the northeast side of Gibson Ridge (Milepost 320, Figure 2.1.2.2-9), then at about Milepost 332 passes through one of the smaller gaps, and thereafter runs along the southwest sides of the various ridges, including Brokenoff Mountain, Paige Mountain, Mount Thomas, and Mount Morrow (Figure 2.1.2.2-10). In places the route is close to the steep sides of the mountains, but elsewhere is a mile or more from the base of the steepest slopes on a belt of glacial deposits or colluvial material derived from the slopes. Southeast of Oscar Creek, at about Milepost 357 (Figure 2.1.2.2-10), the route is adjacent to Discovery Ridge, a higher and more massive ridge than the ones to the north and northwest. Beyond about Milepost 370 the route diverges farther from this ridge than from the ridges to the north, and in fact might be considered to have left the Franklin Mountains and to run at the edge of the Mackenzie Plain from here to about Milepost 405. The proposed route then converges again with the south end of the Norman Range, which ends at about Milepost 414 (Figure 2.1.2.2-10).

Mackenzie Plain--This province is a long and relatively narrow, rolling, tree-covered plain separating the Franklin Mountains and the Mackenzie Mountains, and takes its name from the Mackenzie River, which is incised a few hundred feet into its surface on its eastern side; it is essentially an up-valley continuation of the Peel Plain, but because of its intermontane position it is assigned to the Cordilleran Region rather than the Interior Plains Region, as is the Peel Plain. Between the Norman Range and the McConnell Range to the south, a broad salient of the Mackenzie Plain enters the gap in the Franklin Mountains. It is this salient that the route of the proposed pipeline crosses between about Mileposts 414 and 459 (Figures 2.1.2.2-10 and -11). The Mackenzie Plain is generally of low relief, is dotted by numerous lakes, and is underlain chiefly by fine-grained glacial-lake deposits.

Franklin Mountains-McConnell Range--The Franklin Mountains achieve their fullest development in the McConnell Range (Figures 2.1.2.2-11 through -13), which is longer, broader, and higher than the other ranges, reaching elevations of over 5,000 feet. As with the Norman Range, however, the pipeline route runs chiefly at or away from the base of the range proper, being close to the steep slopes in only a few places, such as near Mileposts 514 and 535 and between Mileposts 547 and 565 (Figure 2.1.2.2-12). There are also several gaps in the range, where the terrain is more like that of the adjacent Mackenzie Plain. Some of the major gaps are near the crossings of Blackwater River (Milepost 504), Ochre River (Milepost 542), and Smith Creek (Milepost 566) (Figure 2.1.2.2-12), and River Between Two Mountains (Milepost 583, Figure 2.1.2.2-13). Minor gaps are present at several places and two of the gaps would be used by the proposed pipeline to cross two low mountain ridges in the Franklin Mountains-McConnell Range near Mileposts 592 and 599. The route leaves the Franklin Mountains and the Cordilleran Region at about Milepost 601.

Great Slave Plain--This physiographic province, within the Interior Plains Region, extends from the southern part of the Franklin Mountains eastward to the Canadian Shield, with Great Slave Lake occupying its east-central part. It is drained by the Mackenzie River, which emerges from Great Slave Lake and makes its way westward across the Great Slave Plain. Thus, like the Great Bear Plain to the north, but unlike most of the Interior Plains as typically developed to the south, the general slope of the plain is to the west, away from the Shield, rather than to the east, away from the Cordillera. The Great Slave Plain has generally low relief. It is underlain by gently dipping to nearly horizontal Paleozoic sedimentary rocks which are generally concealed beneath a veneer of glacial deposits. Some more resistant carbonate rocks form low scarps. Large shallow lakes are also characteristic of this plain, mostly in the eastern and southern parts.

The proposed route traverses only the western part of this province. It enters it at about Milepost 601 (Figure 2.1.2.2-13), crosses Willowlake River at Milepost 605, crosses the Mackenzie River near Milepost 683 (Figure 2.1.2.2-14), and passes about 25 miles east of Trout Lake (Figure 2.1.2.2-15) near the southern end of the province (Milepost 750). Between Mileposts 635 and 645 the route crosses the Ebbutt Hills, a small isolated part of the

Alberta Plateau (discussed in the next section) that is too small to map separately on Figure 2.1.2.3-1.

Alberta Plateau--The proposed route enters this complex physiographic province at about Milepost 750 (Figure 2.1.2.2-15) although it crosses an outlier of the plateau between Mileposts 635 and 645 as described above. The proposed route continues across the Alberta Plateau for the remainder of the distance in Northwest Territories and for much of its distance in Alberta. The Northwest Territories-Alberta border is reached at about Milepost 821 (Figure 2.1.2.2-15). Alberta Plateau is described below.

Description of the Proposed Route South of 60° N Latitude

The southern part of the route of the proposed pipeline is divided into three parts--the southern part of the Main Line, the Monchy Delivery Line (which leads toward the eastern United States), and the Kingsgate Delivery Line (which leads toward the western United States). They would intersect at Caroline Junction, about 80 miles north of Calgary, Alberta. These proposed routes and the physiographic provinces and subprovinces they would traverse are illustrated in Figure 2.1.2.3-2 and are discussed below.

Main Line, Alberta-N.W.T. Border to Caroline Junction

From the northern border of Alberta at 60° N. latitude, near Milepost 821, to Caroline Junction, Milepost 1430, the proposed route lies entirely within the Province of Alberta, and traverses the Alberta Plateau and the Western Alberta Plains (Figure 2.1.2.2-15 through -24).

Alberta Plateau--This physiographic province is a complex of several plateaus separated by lowland areas (Figure 2.1.2.3-2). The plateaus form the farthest northeast parts of relatively high level surfaces that extend from the Cordillera. The Alberta Plateau is drained northward to the Arctic Ocean by the Mackenzie River system. It is broken up into segments separated by broad lowlands that were eroded by the major rivers that occupy them. These lowlands, which make up more than half the area of the Alberta Plateau, are the Fort Nelson Lowland, drained northward by the Nelson/Liard River system and northeastward by the Hay River, and the Peace River Lowland, drained northeastward by the Peace River. The plateau segments traversed by the proposed pipeline route are the Cameron Hills Upland, the Clear Hills Upland, and the Wapiti Plain (grouped for convenience with the plateaus). The plateaus have a generally smooth upland surface that slopes gently northeastward from about 4,300 feet near the Rocky Mountains to elevations of between 2,000 and 3,000 feet overlooking the Great Slave, Saskatchewan, and Alberta Plains. The two broad lowlands that divide the Alberta Plateau into its various segments lie generally at elevations 1,000 feet lower than the surrounding plateaus, and are further incised by the rivers that drain them. Both the plateaus and the intervening lowlands are underlain by Cretaceous sedimentary rocks, but the rocks are generally concealed beneath a cover of glacial deposits.

The route of the proposed pipeline crosses the Cameron Hills Upland between Milepost 750 (Figure 2.1.2.2-15), near Trout Lake, Northwest Territories, and Milepost 885 (Figure 2.1.2.2-16), in Alberta. This subprovince consists of a group of relatively smooth-surfaced uplands (of which the Cameron Hills are but one part) separated by broad lower areas. The proposed route generally follows lower areas between the uplands and avoids steeper slopes and bedrock outcrops. Bistcho Lake, through which the

Petitot River flows, lies in the poorly drained central area, which is underlain by a complex of fine-grained glacial deposits and peat. Although traversing a physiographic plateau (upland), the proposed route actually is crossing terrain that has many of the characteristics of a lowland--namely, poor drainage and fine-grained materials. This is especially true of the long stretch between Mileposts 820 and 875 and a few shorter parts to the north.

By Milepost 885 (Figure 2.1.2.2-16), the proposed route has descended from the Cameron Hills Upland down onto the Fort Nelson Lowland, dropping about 800 feet in elevation. This part of the Fort Nelson Lowland is drained by the Hay River and its principal tributary from the south, the Chinchaga River (Figures 2.1.2.2-17 and -18). Like the area around Bistcho Lake, this area is poorly drained, and is underlain primarily by fine-grained glacial-lake deposits. Just upstream from where the proposed route crosses the Hay River, the river passes through a large marshy area occupied by the Zama Lake complex. The proposed route avoids this area, passing to the east of it, but does traverse low-lying, poorly drained ground. South of the Hay River area the proposed route continues south near Sousa Creek, which flows north, parallel to the Chinchaga River. This area is also low and poorly drained, and is adjacent to the northeast corner of the Clear Hills Upland.

At about Milepost 947 (Figure 2.1.2.2-17) the proposed route climbs onto the edge of the Clear Hills Upland. Like the Cameron Hills Upland, this subprovince consists of a group of hills with generally smooth surfaces separated by intervening lower areas, all above the general level of the major lowlands. The first sector of the Clear Hills Upland traversed, as far as about Milepost 970, is similar in character to the poorly drained parts of the Cameron Hills. Between Mileposts 970 and 983, the Clear Hills Upland is interrupted by a salient of the adjacent Fort Nelson Lowland, where the valley of the Chinchaga River is crossed (Figure 2.1.2.2-18). At about Milepost 983 the proposed route climbs onto the north edge of the Naylor Hills, and between here and the end of this subprovince, at Milepost 1087 (Figure 2.1.2.2-19), crosses uplands that are more irregular in topography but better drained than the uplands to the north. These northeast- to southeast-trending hills are separated by the valleys of the generally east-flowing Botha, Meikle, Hotchkiss, and Whitemud Rivers (Figures 2.1.2.2-18 and -19). These valleys comprise relatively narrow belts of smoother topography. The Notikewin River, the largest of the east-flowing rivers, into which all but the Whitemud River drain, has a broad valley of poorly drained ground. The most rugged of the hilly upland sectors of this subprovince is the Whitemud Hills, the crest of which is crossed near Milepost 1080 (Figure 2.1.2.2-19). The proposed route then descends to the Peace River Lowland.

From Milepost 1087 to Milepost 1148 (Figure 2.1.2.2-20), the proposed route crosses the Peace River Lowland, which extends across the Alberta Plateau, following the Peace River nearly all the way in its northeastward journey from the Cordillera to the Canadian Shield. The lowland has a generally even surface, sloping imperceptibly northeastward. The Peace River and its major tributaries are deeply incised below this surface with very steep bluffs 500 to 1,000 feet high bordering the rivers. This lowland is underlain by thick glacial-lake deposits, dominantly silt and clay, and the surface contains some small present-day lakes and marshy land. Much of it, however, has been drained for agricultural purposes. At Milepost 1112 (Figure 2.1.2.2-20) the proposed route crosses the Peace River in a stretch where the bluff slopes are somewhat less steep than elsewhere, probably because of extensive mass wasting (landsliding), but still are about 600 feet high. The Smoky River is crossed near Milepost 1141 (Figure 2.1.2.2-20) and is bounded by very steep 400-foot bluffs. A short distance to the south, as the edge of the lowland is approached, the land slopes gently upward. The proposed route leaves the lowland at about Milepost 1148.

From Milepost 1148 to Milepost 1247 (Figure 2.1.2.2-21) the proposed route crosses the southernmost segment of the Alberta Plateau, here referred to as the Wapiti Plain. This subprovince has characteristics of both a plain and a lowland, but its overall elevation places it in the higher parts of the Alberta Plateau. It extends eastward from the Rocky Mountain Foothills to the Swan Hills Upland, an outlier of higher ground capped by younger rocks. The terrain is generally smooth and sloping to the east, but in places there are hills of somewhat rougher topography and higher elevation, and river valleys with lowland characteristics. The proposed route first crosses one of the higher parts of this plain, an upland between the Puskwaskau River and the Little Smoky River, as far as about Milepost 1169 (Figure 2.1.2.2-20), where it descends to the valley of the Little Smoky. It then proceeds southward up this relatively flat-floored valley and that of the tributary Iosegun River to about Milepost 1234 (Figure 2.1.2.2-21). These valleys mark the approximate boundary between this subprovince and the Swan Hills Upland to the east. For the last 13 miles, to Milepost 1247, the proposed route crosses another high part of the plain, reaching elevations above 3,000 feet, before descending to cross the Athabasca River and enter the Western Alberta Plains Province. This last segment of the Wapiti Plain has many of the characteristics of the Western Alberta Plains.

Western Alberta Plains--This physiographic province borders the Rocky Mountain Foothills to the west and extends eastward and northeastward for about 75 miles, comprising the highest of the various plains that lie east of the mountains; the Eastern Alberta Plains are lower and broader. There are both geologic and physiographic distinctions between the two, the Western Alberta Plains being underlain by younger (Tertiary) rocks, and having somewhat greater relief with a more undulating surface. The western plains were the sites of greater deposition of material from the mountains as the latter were being elevated. Today this thicker pile of deposits is undergoing more extensive erosion than the lower lying rocks to the east; the eastern plains have already had removed from them rocks equivalent to some of those that are still preserved to the west. Bedrock is concealed in most places beneath a cover of glacial moraine and lake deposits. The Western Alberta Plains slope gently to the east and northeast from elevations near 4,000 feet at the foothills to 2,500 feet at the transition to the eastern plains. The major rivers are entrenched 200 to 400 feet below the general surface.

The proposed route enters the Western Alberta Plains at Milepost 1247, crosses the Athabasca River shortly thereafter, and then climbs onto a general surface somewhat over 3,000 feet in elevation, continuing southeastward across this surface, crossing Windfall Creek near Milepost 1261 and the McLeod River near Milepost 1291 (Figure 2.1.2.2-22), and the Pembina River near Milepost 1341 (Figure 2.1.2.2-22), reaching the North Saskatchewan River at about Milepost 1352 (Figures 2.1.2.2-22 and -23). The narrow ridge between the Pembina River and the North Saskatchewan River marks the divide between Arctic Ocean and Hudson Bay drainages. From here the route parallels the North Saskatchewan River in an atypical north-south stretch to about Milepost 1398 near Rocky Mountain House (Figure 2.1.2.2-23). From here to the end of the Main Line at Caroline Junction, Milepost 1430 (Figure 2.1.2.2-24), the terrain is somewhat smoother but generally rising in elevation as the western edge of the plains next to the Rocky Mountain foothills is approached.

Monchy Delivery Line

The proposed Monchy Delivery Line begins at Caroline Junction in the Western Alberta Plains, runs southeastward onto the Eastern Alberta Plains, and continues to its terminus at the Canada-U.S. border near Monchy (Figure 2.1.2.3-2; Figures 2.1.2.2-24 through -28).

Western Alberta Plains--This physiographic province was described in general terms in the section on the main line in Alberta. The route of this segment of the Monchy Delivery Line from Milepost 0 to Milepost 40 (Figure 2.1.2.2-24) is on a gently undulating to smooth plains surface, staying close to 3,500 feet in elevation. Between Mileposts 40 and 80 (Figure 2.1.2.2-24 and -25) the route generally parallels the Rosebud River, descending gently in elevation to below 3,000 feet. From about Milepost 90 to the eastern edge of this physiographic province, at about Milepost 122, the route crosses the Wintering Hills subprovince, a higher area over 3,000 feet in elevation with a somewhat more rugged, dissected surface (Figure 2.1.2.2-25).

Eastern Alberta Plains--This large physiographic province occupies much of eastern Alberta and southwestern Saskatchewan. In general it comprises smooth terrain that slopes gently eastward, ending at the Missouri Coteau, an escarpment that overlooks the still lower Saskatchewan Plain. The major rivers, however, are incised as much as 400 feet below the general surface. Most of the Eastern Alberta Plains do not have many hills rising above their surface, but in the southern part, within about 50 miles of the Canada-U.S. border, there is a series of hills, including the Cypress Hills and Wood Mountain, that in effect are outliers of the higher Western Alberta Plains. This higher area also marks, in a general way, the divide between Hudson Bay drainage to the north and Gulf of Mexico drainage to the south.

Where it first enters the Eastern Alberta Plains at Monchy Delivery Line Milepost 122, the proposed route is in typically smoothly sloping plains terrain and roughly parallels the Red Deer River as far as Milepost 234 (Figure 2.1.2.2-26). Between Mileposts 195 and 210 it crosses a higher, somewhat more unevenly surfaced area, and between Mileposts 220 and 226 crosses the Middle Sand Hills, an area of largely stabilized sand dunes. Near Milepost 229, steep bluffs 400 feet high at the crossing of the South Saskatchewan River also interrupt the general surface. The proposed route then turns southeastward across an area that generally decreases in elevation to about 2,300 feet and is characterized by poorly organized drainage with many intermittent stream channels and lakes. Between Mileposts 275 and 295 the route crosses part of the Great Sand Hills, an area of active sand dunes and some large lakes (Figure 2.1.2.2-27). The surface generally rises in elevation, and between Mileposts 309 and 324 crosses the eastern extremity of the Cypress Hills where some elevations are higher than 3,200 feet (Figure 2.1.2.2-28). Southeast of here, the smoother topography typical of the plains resumes. In this stretch the divide between Hudson Bay and Gulf of Mexico drainage is passed. This generally smooth surface continues to the Canada-U.S. border, gradually decreasing in elevation to about 2,700 feet. The smooth surface is interrupted only by an area of strongly dissected topography between Mileposts 350 and 360 near the crossing of Frenchman River (Figure 2.1.2.2-28).

Kingsgate Delivery Line

This segment of the proposed route begins in the Western Alberta Plains, runs southward through the west edge of this province, and then

PROPERTY OF
Bureau of Land Management
DSC LIBRARY

turns to run generally southwesterly across the Eastern System of the Cordilleran Region. In crossing this large mountain complex it traverses, in order, the Rocky Mountain Foothills, the Rocky Mountains, the Rocky Mountain Trench, and the Columbia Mountains (Figure 2.1.2.3-2; Figures 2.1.2.2-29 through -31).

Western Alberta Plains--This province was described in the section on the proposed Main Line in Alberta. Between Caroline Junction Milepost 0 and about Milepost 57 just south of the Bow River (Figure 2.1.2.2-29), the Kingsgate Delivery Line crosses gently undulating country typical of the high plains. The surface is broken primarily near major river crossings, where there are bluffs up to 250 feet high, in particular at the Red Deer River, Milepost 12, and the Bow River, Milepost 55. From there to about Milepost 120 (Figure 2.1.2.2-30) the route follows the western edge of the Western Alberta Plains, with the Rocky Mountain Foothills just to the west. The terrain retains the dominant high plains characteristics, however, being generally smooth surfaced to gently undulating, with the surface interrupted by only a few hills, and by some stream crossings where the streams are incised 100 to 200 feet below the general surface.

Rocky Mountain Foothills--This is a long narrow province that extends the length of the Rocky Mountains, bordering them on the east, from the Liard River in northern British Columbia to the Canada-U.S. border. Although 850 miles long, the belt is only about 30 miles wide, and consists of linear ridges, dominantly of sandstone, that rise abruptly from the plains to the east, that have relief of 500 to 1,000 feet, and that reach elevations of between 5,000 and 7,000 feet. The proposed route enters this province at about Milepost 120, and crosses it by traversing a series of valleys, mostly tributary to Willow Creek, so that the ridges that are characteristic of the province are skirted rather than transected; the route is thereby able to maintain the more gentle gradients of the valleys rather than climb the steeper slopes characteristic of the foothills.

Rocky Mountains--These mountains extend for more than 850 miles, from northern British Columbia southward into the United States, and sit astride the Continental Divide separating Arctic Ocean and Atlantic Ocean drainage from that of the Pacific Ocean. The southern part of the Canadian Rockies is called the Continental Ranges. They comprise a broad series of linear ranges with high cliffs, the precipitous faces of which were sculptured by glacier ice from the thick carbonate sedimentary rocks which make up most of the ranges. They rise in elevation to over 12,000 feet, and many of the higher peaks contain glaciers, especially in the vicinity of the Columbia Icefield.

The proposed route crosses the Continental Ranges at a relatively low part, where the peaks are generally 8,000 to 9,000 feet high. At about Milepost 136 (Figure 2.1.2.2-30) the line would climb out of a valley in the foothills and cross the Livingstone Range in a series of long steep slopes. The proposed route then follows down one valley and up another, crossing various ranges at relatively low saddles between the peaks to reach the Continental Divide at Crowsnest Pass (Milepost 176; Figure 2.1.2.2-30). Highway 3 and the southern line of the Canadian Pacific Railway also cross the divide over Crowsnest Pass. To the southwest, the proposed route continues across the ranges by traversing one valley up to its head, crossing a relatively low divide, and going down another valley until at about Milepost 218 the route emerges from a break between the Lizard Range and the Galton Range into the Rocky Mountain Trench (Figure 2.1.2.2-31).

Rocky Mountain Trench--This long and very narrow province borders the Rocky Mountains on their west and, with a few interruptions, forms a single long valley-like feature a few to more than 15 miles wide bounded by many different faults and occupied by a series of rivers that head in it or run along it for part of their courses. Among these are the Finlay, Fraser, and Columbia Rivers. In the vicinity of the proposed route crossing, the trench is occupied by the Kootenay River, whose flat-floored valley the route crosses between Mileposts 218 and 232 (Figure 2.1.2.2-31).

Columbia Mountains--West of the southern part of the Rocky Mountain Trench lie the Columbia Mountains, which are similar in many characteristics to the Rockies, rising in rugged glaciated peaks to elevations of more than 10,000 feet. They are composed, however, mostly of Precambrian crystalline rocks. In the vicinity of the proposed route, the peaks are between 6,000 and 7,000 feet high. The route crosses the range between Milepost 232 and the British Columbia-Idaho border at about Milepost 281 (Figure 2.1.2.2-31) by going up Tepee Creek through the McGilvary Range, crossing the Yahk Range, and then following the valley of the Moyie River to the International Boundary.

Bedrock

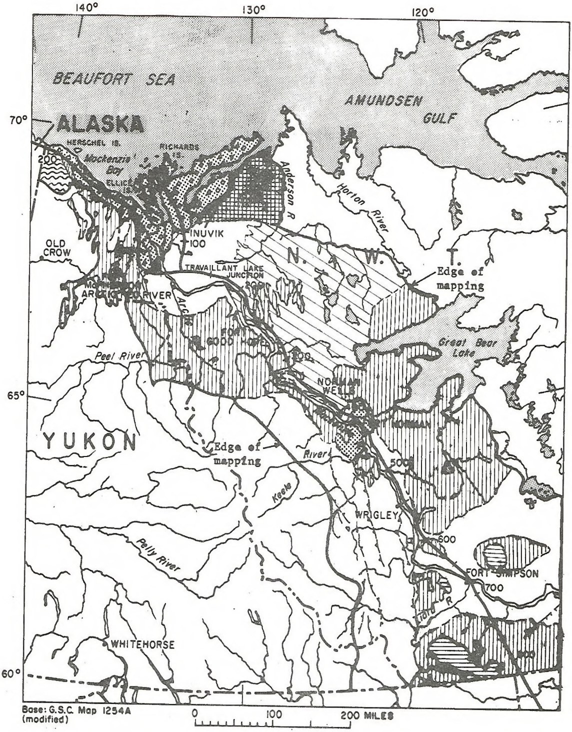
The bedrock geology discussed in this section and shown on Figures 2.1.2.3-3 and 2.1.2.3-4 has been generalized from the geological map of Canada (Canada Geol. Survey, 1969) and the map, Geology of Yukon and Northwest Territories (Canada Geol. Survey, 1963).

Almost all of the rocks underlying the route of the proposed pipeline are bedded sedimentary rocks, ranging from hard metamorphosed rocks to poorly consolidated shale. Precambrian rocks are mainly argillite and quartzite, the Paleozoic (chiefly Devonian) rocks are mainly limestone and sandstone, the Cretaceous are mainly shale and sandstone, and the Tertiary are mainly sandstone and conglomerate. Significant amounts of anhydrite are present in the Devonian rocks, carbonaceous and bentonitic shales and coal in Cretaceous rocks, and lignite in rocks of Tertiary age.

North of 60° N. latitude most beds, except in the Franklin Mountains, have simple structure and are generally flat lying or dip at low angles to the west or south. South of the 60° N. latitude, except in southeastern British Columbia, the structure is also relatively simple. Rocks in the Franklin Mountains and in southeastern British Columbia are structurally more complicated and are extensively thrust faulted and folded.

The bearing capacity and other physical properties of the rocks vary widely, but most of them are relatively competent (that is, able to carry the loads imposed upon them by most engineering structures). The chief exception is shale, which generally has a relatively low bearing capacity and thus has a low suitability for engineering uses. Bentonitic shale, in particular, is a rock that gives rise to engineering problems because of its great potential for swelling. Coal and anhydrite are also rocks of very low bearing capacity and are even less suitable than shale for most engineering uses.

Glacial deposits commonly conceal bedrock along much of the proposed route except in the mountains. Elsewhere, bedrock would be encountered chiefly on slopes, some quite steep, adjacent to stream crossings.



Base: G.S.C. Map 1254A (modified)

Figure 2.1.2.3-3 Bedrock geology in the region of the proposed route north of 60° N latitude

EXPLANATION

⁘	Tertiary-Quaternary undivided, sand, gravel, and silt; generally can be considered as surficial materials
░	Tertiary sandstone, siltstone, conglomerate, clay and shale layers; lignite
▦	Cretaceous undivided, sandstone and shale, not on route
▤	Upper Cretaceous undivided, thin-bedded, laminated, crossbedded sandstone; fissile, rubbly, concretionary shale; conglomerate; coal
▥	Lower Cretaceous undivided, basal sandstone, bentonitic and bituminous shale, siltstone, sandstone
□	Upper Devonian undivided, sandstone, shale, mudstone, petroliferous and bituminous shale (combustible); includes all Paleozoic rocks west of route and south of 65° N latitude
▧	Middle Devonian undivided, includes Cambrian, Ordovician, and Silurian sedimentary rocks, mainly carbonates; forms sinks and caverns; shale and sandstone in upper part, bituminous shale (combustible)
≋	Precambrian argillite and quartzite

SYMBOLS

—+—	Milepost for proposed pipeline
— — —	Contact between map units
▲ ▲ ▲	Thrust fault
⊥ ⊥ ⊥	Normal fault

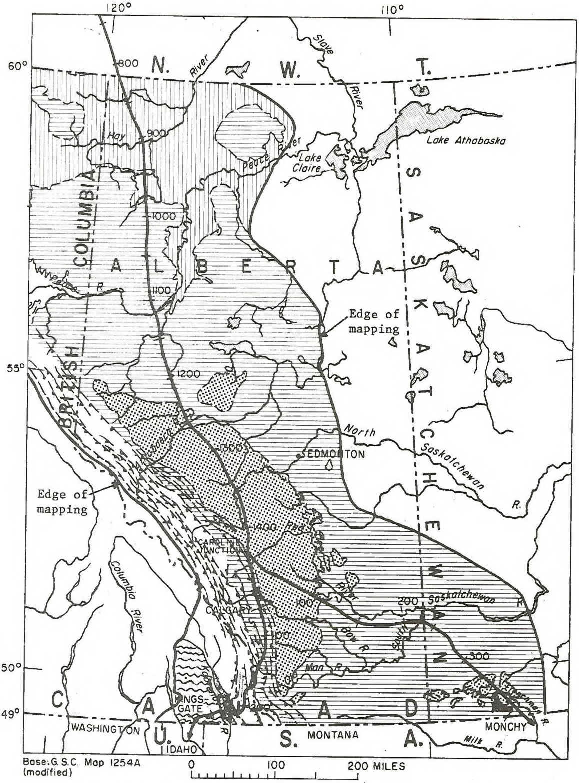


Figure 2.1.2.3-4 Bedrock geology in the region of the proposed route south of 60° N latitude

EXPLANATION

⁘	Tertiary-Quaternary undivided, sand, gravel, and silt; generally can be considered as surficial materials
░	Tertiary sandstone, siltstone, conglomerate, clay and shale layers; lignite
▦	Cretaceous undivided, sandstone and shale, not on route
▤	Upper Cretaceous undivided, thin-bedded, laminated, crossbedded sandstone; fissile, rubbly, concretionary shale; conglomerate; coal
▥	Lower Cretaceous undivided, basal sandstone, bentonitic and bituminous shale, siltstone, sandstone; includes Triassic and Jurassic sedimentary rocks in northwestern part of map area
□	Upper Devonian undivided, sandstone, shale, mudstone, petroliferous and bituminous shale (combustible); includes all Palezoic rocks west of route and south of 65° N latitude
▧	Middle Devonian undivided, includes Cambrian, Ordovician, and Silurian sedimentary rocks, mainly carbonates; forms sinks and caverns; shale and sandstone in upper part, bituminous shale (combustible)
≋	Precambrian argillite and quartzite

SYMBOLS

─┼─	Milepost for proposed pipeline
– – –	Contact between map units
— — —	Thrust fault
┴┴ ┴┴ ┴┴	Normal fault

North of 60° N. Latitude

Prudhoe Bay Supply Line

The proposed Prudhoe Bay Supply Line crosses the Alaska-Yukon Territory border at Milepost 195, and traverses for several miles undifferentiated Quaternary and Tertiary sand and gravel that overlies steeply dipping Precambrian argillite and quartzite. To about Milepost 340 bedrock mostly is covered by Quaternary or Tertiary unconsolidated sediments but it is known to include patches of Triassic and Jurassic sedimentary rocks. From Milepost 340 to near Fort McPherson (about Milepost 430), bedrock is mainly deformed Jurassic and Cretaceous shale, siltstone, and sandstone. Locally, some of the rocks are bentonitic. In many places bedrock is covered by Quaternary alluvium. From near Fort McPherson to Travaillant Lake Junction (Milepost 492), flat-lying Devonian sandstone, shale, and mudstone are present.

Richards Island Supply Line

The proposed Richards Island Supply Line starts in Quaternary deltaic sediments consisting of mud, sand, and silt. At Milepost 7, it passes onto Tertiary and Quaternary deposits composed of poorly consolidated to unconsolidated conglomerate and sandstone with some shale and lignite. The proposed Parsons Lake Lateral Line, which joins the Richards Island Supply Line at Milepost 40, also would cross these materials. The Devonian rocks first encountered (Milepost 90) along the proposed route are carbonates of the Bear Rock Formation which includes some anhydrite. These rocks may be cavernous. At Milepost 95 these rock types are succeeded by Middle Devonian sandstone, shale, and mudstone with some limestone. A short distance beyond Milepost 95 Upper Devonian sandstone and shale are present and extend to the end of the Richards Island Supply Line.

Main Line

Sandstone and shale of Upper Devonian age are present along the Main Line from its beginning to Milepost 170. From there to Fort Good Hope (Milepost 287) the proposed route crosses Middle Devonian calcareous siltstone, shale, and some limestone with patches of Lower Cretaceous shale and sandstone, including interbedded bentonite and a basal quartz sandstone.

From Fort Good Hope south to about Fort Norman (Milepost 420) the proposed route traverses deformed Cambro-Ordovician carbonate rock and Middle and Upper Devonian limestone, shale, and siltstone. Some of these rocks are part of the Bear Rock Formation. The complex structure of these strongly folded and faulted rocks is in marked contrast to the relatively undeformed rocks that occur farther south.

Between about Mileposts 420 and 440, the proposed route crosses flat-lying Tertiary conglomerate and sandstone which contain some shale and lignite. In the Fort Norman region some lignites are currently burning underground. Beyond Milepost 440 to about Milepost 600 the proposed route again crosses deformed Cambro-Ordovician and Devonian carbonate rocks. The route between Milepost 600 and 730 crosses gently dipping or flat-lying Devonian shale and siltstone with outliers of Lower Cretaceous shale. The remainder of the proposed route extending to 60° N latitude traverses shale of Lower Cretaceous age.

South of 60° N Latitude

Main Line to Caroline Junction

The proposed route continues southward from 60° N latitude (Milepost 821) on flat-lying Lower Cretaceous shale to about Milepost 980. From there to Milepost 1240 along the proposed route, bedrock is generally flat-lying Upper Cretaceous shale and sandy shale. The rest of the proposed route to the end of the Main Line at Caroline Junction crosses Tertiary sandstone and mudstone containing some lignite beds.

Monchy Delivery Line

The proposed Monchy Delivery Line starts at Caroline Junction and for 110 miles crosses an area underlain by flat-lying Tertiary rocks which are mainly sandstone, but contain minor amounts of shale and coal. Between Mileposts 110 and 330 the proposed route traverses Upper Cretaceous shale with minor amounts of sandstone, some coal seams, and bentonite; in the Alberta part of this segment rocks dip gently to the west but in the Saskatchewan part of the segment, rocks are flat lying. From Milepost 330 to the International Boundary (Milepost 394), bedrock is Upper Cretaceous and Tertiary in age and consists mainly of sandstone and shale with some bentonite beds. These rocks dip gently to the east.

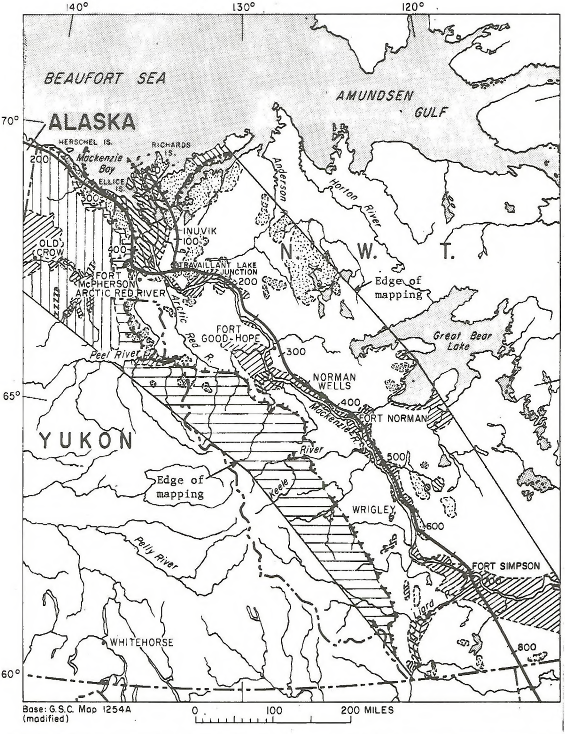
Kingsgate Delivery Line

The proposed route starts at Caroline Junction in an area underlain by Tertiary sandstone, conglomerate, siltstone, mudstone, shale, and lignite beds. From the western limit of Tertiary rocks (about Milepost 128) to the Rocky Mountain Front (Milepost 175), bedrock is similar but is of Upper Cretaceous age and is cut by several thrust faults including the major Lewis thrust fault. The Continental Ranges of the Rocky Mountains are composed mainly of extensively faulted Paleozoic and Precambrian argillite, sandstone, and carbonate rocks. At about Milepost 220 the proposed route enters and then crosses that part of the Rocky Mountain Trench drained by the Kootenay River (Milepost 231). The trench is a deep valley bounded irregularly by faults that cut rocks of several ages. The proposed route between the Rocky Mountain Trench and the Moyie River valley, as well as that part of the route along the valley, traverses Precambrian metamorphic rocks which are mainly argillite and quartzite. The major Moyie fault obliquely crosses the Moyie River valley near the International Boundary (approximately Milepost 281) and continues southward into the United States. None of the faults within the area crossed by the Kingsgate Delivery Line apparently cut bedrock or surficial deposits as young as Quaternary in age.

Surficial Deposits

North of 60° N Latitude

A variety of surficial deposits is exposed along the route of the proposed pipeline (Figure 2.1.2.3-5). In decreasing order of abundance in the general area along the pipeline, these are: (1) deposits of the last major glaciation, (2) deposits of postglacial weathering and sedimentation, (3) deposits from earlier glaciations, and (4) mantles of frost-shattered rock on glaciated bedrock surfaces. All of these deposits are engineering soils in a broad sense; agricultural soils are separately discussed in Section 2.1.2.4.



Base: G.S.C. Map 1254A (modified)

Figure 2.1.2.3-5 Surficial deposits in the region of the proposed route north of 60° N latitude

EXPLANATION

Deposits are of Wisconsin (last glacial) age except as noted.

▨	Chiefly lacustrine deposits: silt, clay, and some sand. In part early postglacial in age
▧	Chiefly alluvial deposits: sand and/or gravel; commonly dune covered. Includes outwash plains, valley trains, and deltas. In part postglacial in age
□	Mainly smooth to gently rolling ground moraine plains of variably stony diamicton (till) having a fine-grained matrix. Includes alluvial deposits, some of which are postglacial in age
▒	Principally hummocky moraine of stony diamicton (till). Includes complexes of end, lateral, and kame moraines. In part pre-Wisconsin in age
▤	Mostly ground moraine of variably stony diamicton (till) of pre-Wisconsin age. Includes some thin and patchy deposits in unglaciated areas
▥	Thin and patchy deposits in unglaciated areas: (1) rubble developed from in-place weathering of bedrock, (2) colluvium of variable texture, and (3) wind-transported silt and sand. Pre-Wisconsin and younger in age

SYMBOLS

—+—	Milepost for proposed pipeline
— — — —	Contact between map units
⊥⊥ ⊥⊥ ⊥⊥	Outer limit of Wisconsin (last) Laurentide continental ice sheet; ticks on glacier side of line

During the last major glaciation most of northwestern Canada was covered by the Laurentide Continental Ice Sheet. At the time of its maximum extent, about 13,000 years ago, glacier ice abutted the eastern margins of the Mackenzie and Richardson Mountains and a lobe of ice reached northwestward along present-day Mackenzie Bay and the Yukon coastal plain to the vicinity of Herschel Island (Prest, 1970). During the last major glaciation ice did not cover the area northeast of the Mackenzie River delta. Earlier glaciations were more extensive.

About 10,000 years ago, melting and retreat of the Laurentide Ice Sheet near the Mackenzie River was largely completed. As a result, glacier-smoothed bedrock and a variety of glacial and glacier-related deposits were exposed. These include: (1) glacial diamicton (till) consisting of sand and (or) gravel particles in a matrix of silt and (or) clay; commonly the material is a variable stony to sandy silt and clay, forming hummocky or smooth ground-moraine plains; (2) sand and gravel deposited in rivers, fans, lakes, deltas, and beaches, and in and around glacier ice (ice-contact deposits); (3) sand and silt in areas of wind sedimentation; and (4) silt and clay laid down in lakes, near-shore marine areas, and deltas.

During postglacial times, the surface and upper parts of the glacial deposits were locally modified by running water, freezing and thawing, gravity-caused movements, wave action, wind, vegetation growth (peat), and the development of permafrost. As a result, some glacial deposits were eroded and others were covered by products of postglacial sedimentation. Postglacial sediments that are especially prevalent include: (1) alluvial sand, gravel, and silt; (2) colluvial material ranging in size from silt to large blocks of bedrock rubble; (3) peat; (4) windblown sand and silt; (5) lacustrine and marine silt and clay; and (6) lacustrine and marine near-shore sand and gravel.

In the following descriptions of the surficial deposits along the proposed route, linear segments having similar sediments are identified by route mileposts. The descriptions are generalized from many different reports, including: Boydell and Rutter (1973), Canadian Arctic Gas Pipeline Ltd. (1974a, b, d, e), Hanley and Hughes (1973), Prest, Grant, and Rampton (1968), and Rampton (1972, 1974).

Prudhoe Bay Supply Line

Mileposts 195-205--Alluvial fans composed of medium- to coarse-grained sandy gravel, and, locally, fine sand and silt. Fans probably are at least 20 feet thick. Locally, there are ice-rich lake and colluvial deposits of silt and organic silt.

Mileposts 205-218--Colluvial silt and organic silt with a high ice content.

Mileposts 218-225--Gravelly alluvium of the present and ancestral Malcolm River. Deposits are probably more than 20 feet thick. Older alluvium is covered by ice-rich silt.

Mileposts 225-235--Generally thin, ice-rich, fine-grained colluvium, and gravelly alluvium locally covered by as much as 12 feet of ice-rich organic material.

Mileposts 235-252--Mostly rolling moraines containing glacial diamicton (till) composed of variably stony, ice-rich silt and clay. Some fine-grained colluvial deposits of ice-rich organic silt are present. Deposits may be as much as 30 feet thick.

Mileposts 252-277--Gravelly glaciofluvial deposits probably more than 10 feet thick. Locally, ice-rich glacial diamicton in moraines, and ice-rich lake or colluvial deposits of silt and clay. Ice-rich organic silt deposits as much as 12 feet thick cover many glaciofluvial and lake deposits.

Mileposts 277-305--Silt-mantled rolling to flat moraines containing glacial diamicton, probably with a high silt, clay, and ice content. Bedrock locally may be within 5 feet of the surface. Also present are several lake and colluvial deposits, both consisting of ice-rich silt or organic silt.

Mileposts 305-330--Morainal deposits composed of glacial diamicton, probably with a high content of silt, clay, and ice; ice-rich lake silt; and glaciofluvial gravel. Units are extensively covered by ice-rich organic materials. Bedrock is within 5 feet of the surface locally.

Mileposts 330-376--Glacial diamicton, probably with high silt, clay, and ice content. Alluvial silt and fine sand are crossed near the margin of the Mackenzie River flood plain between Mileposts 361 and 365. Some alluvial fans ranging in composition from silt to gravel are adjacent to the flood plain. Bedrock is locally within 5 feet of the surface. Morainal landforms vary in slope from flat to moderately steep.

Mileposts 376-415--Ice-rich silt and organic silt and fine sand of coalescing alluvial fans. The deposits are probably more than 20 feet thick. A silty landslide of probably the mudflow type lies near the proposed pipeline route between Mileposts 392 and 394. The landslide originated on a mountain to the west of the route and moved downslope to a position near the route. Between Mileposts 408 and 410 the route crosses diamicton, presumably of glacial origin.

Mileposts 415-463--Mostly hummocky moraine composed of glacial diamicton locally interspersed with: alluvial fans containing ice-rich silt and fine sand; flood-plain deposits of ice-rich silt, clay, and fine sand near the Peel River and other stream crossings; and ice-rich lacustrine silt and clay. Ice-rich organic material averaging 2 to 7 feet thick may be found between hillocks in the areas underlain by moraines and lake deposits.

Mileposts 463-492--Glacial diamicton in hummocky moraines and a few sandy gravel deposits in glaciofluvial and ice-contact landforms. Locally, there are ice-rich lake-clay and silt deposits as much as 7 feet thick overlain by ice-rich organic material.

Richards Island Supply Line

Mileposts 0-3--Interbedded ice-rich deposits of silt, clay, fine sand, and organic material. Deposits are part of the Mackenzie River delta.

Mileposts 3-19--Gently rolling to hummocky moraine composed of glacial diamicton probably having a high percentage of silt and clay. Postglacial lacustrine deposits of clay, silt, fine sand, and organic material mantle depressions on the moraine surface, especially between Mileposts 5 and 7 and between 8 and 9. Lacustrine deposits are ice-rich and may be as much as 7 feet thick. An area of glacial outwash composed of sand and (or) gravel is located between Mileposts 14 and 16.

Mileposts 19-24--Thin organic material and silt overlying flood-plain deposits as much as 15 feet thick consisting of sand, silt, and some gravel adjacent to the Mackenzie River. All deposits are ice-rich.

Mileposts 24-32--A veneer of deltaic silty sand and silt overlying glacial diamicton at depths of probably less than 15 feet. Numerous small organic and lacustrine deposits cover the deltaic and glacial deposits. All materials are ice rich.

Mileposts 32-39--Ice-contact deposits of sand and (or) gravel and hummocky morainal deposits of glacial diamicton having a moderately high percentage of silt and clay. All deposits are permanently frozen.

Mileposts 39-57--Rolling to hummocky ground moraine composed of ice-rich glacial diamicton, generally less than 7 feet thick above bedrock. Some depressions in the ground moraine are partly filled with frozen, silty lake deposits and organic materials possibly as much as 7 feet thick. Large depressions are located near Milepost 53 and between Mileposts 51 and 52.

Mileposts 57-87--A veneer of ice-rich clay and silt of probable lacustrine origin overlying mostly glacial diamicton; the proposed route between Mileposts 80 and 86 probably crosses bedrock. The lake deposits are probably from 5 to 20 feet thick. Frozen organic deposits and silty to gravelly alluvial deposits are scattered along the route, especially near Mileposts 66, 78, and 81.

Mileposts 87-93--Ice-rich deposits consisting of (1) glacial diamicton and some ice-contact deposits; (2) a thin veneer of lacustrine clay and silt overlying diamicton; (3) alluvial deposits of clay, silt, and fine sand; and (4) organic deposits overlying alluvium or glacial deposits.

Mileposts 93-143--Rolling ground moraine underlain by ice-rich, stony diamicton with high silt and clay content. These materials may be less than 15 feet thick over bedrock between Mileposts 93 and 125. Ice-rich organic deposits less than 10 feet thick partially fill depressions in the moraine surface, especially at Mileposts 103, 104, 127, and 134. Thin ice-rich colluvial silt and organic silt cover large areas of the ground moraine.

Parsons Lake Lateral Line

Mileposts 0-11--Hummocky moraine consisting predominantly of glacial diamicton having a large percentage of ice-rich silt and clay, and some glaciofluvial deposits of frozen sand and (or) gravel. Deposits of silt or organic silt irregularly cover the glacial deposits, especially in depressions. The silts are ice rich and may be as much as 10 feet thick.

Mileposts 11-15--Less than 7 feet of ice-bearing glacial diamicton overlying bedrock. Locally, a few feet of silt or organic silt covers the glacial deposits. (Junction with Richards Island Supply Line is at Milepost 15.)

Main Line

Mileposts 126-146--Hummocky moraines composed of glacial diamicton with a high ice content. Bedrock locally may lie within 20 feet of the surface.

Mileposts 146-152--Ground moraine consisting of ice-rich diamicton locally covered by ice-rich glaciolacustrine silt and clay averaging 6 feet thick.

Mileposts 152-162--Ice-rich surficial deposits, which probably average 20 feet in thickness, consist of: (1) glaciolacustrine silt, clay, and some sand; (2) organic materials, predominantly peat; and (3) a few hummocky moraines of diamicton.

Mileposts 162-174--Moraine composed of diamicton locally having a high silt, clay, and ice content. A mantle of ice-rich glaciolacustrine silt and clay locally covers the diamicton and may average 6 feet in thickness.

Mileposts 174-187--Rolling to hummocky moraines composed of ice-rich glacial diamicton. Occurring locally are ice-contact deposits of sand and gravel and numerous peat and lake deposits.

Mileposts 187-205--Glaciolacustrine deposits of ice-rich silt and clay as much as 40 feet thick. Alluvial fans of ice-rich silt and sand and ice-rich organic deposits occur locally.

Mileposts 205-219--Alluvial fans that head to the left (northeast) of the alinement and some fine-grained glacial lake and deltaic deposits. The fan deposits are largely ice-rich silt with minor amounts of sand and gravel. The glacial lake deposits are clay and silt locally overlain by alluvium and landslide deposits. The ice-rich deltaic deposits consist of silt and fine sand.

Mileposts 219-266--Rolling to hummocky ground moraine composed of glacial diamicton commonly overlain by ice-rich colluvial silt and clay. Bedrock or older ice-rich drift is exposed locally. There are several areas (near Mileposts 248, 249, and 255) of organic deposits more than half a mile in maximum dimension. Most of these probably have a high ice content and overlie diamicton at depths of less than 6 feet.

Mileposts 266-306--Gently rolling plain of ground moraine underlain by perennially frozen glacial diamicton irregularly mantled by sandy to gravelly silt as much as 5 feet thick. The sand and gravel are products of wave action in a glacial lake. Ice-rich organic deposits are locally present. Deposits of sand and subordinate gravel in eskers, kames, flood plains, deltas, and dune fields occur between Mileposts 284 and 288 near the Hare Indian River crossing.

Mileposts 306-318--Ice-rich silt and clay formed in small lakes. Locally there are small deposits of peat and areas of glacial diamicton having a few-feet-thick veneer of silty gravel winnowed by waves in short-lived postglacial lakes.

Mileposts 318-331--Rolling ground-moraine plains of diamicton mantled by ice-rich, colluvial, silty clay and sand probably less than 5 feet thick. Bedrock is locally exposed at the surface.

Mileposts 331-338--Ice-rich glaciolacustrine silt and clay as much as 40 feet thick. Active colluvial deposits occur west of the alinement between Mileposts 333 and 335.

Mileposts 338-340--Bedrock thinly covered by glacial deposits. Some sinkholes may be present that are filled with glacial deposits.

Mileposts 340-358--Glacial lake deposits of ice-bearing silt, clay, and subordinate sand as much as 20 feet thick. Active colluvial talus deposits occur left (northeast) of the route between Mileposts 350 and 355. Some glaciofluvial sand and gravel are present between Mileposts 347 and 350, and between 355 and 357.

Mileposts 358-365--Mostly alluvial fans composed of ice-rich organic silt, sand, and some gravel. Thin deposits of lacustrine silt and clay are present over bedrock. The lake sediments may average 10 feet in thickness. Bedrock is exposed locally.

Mileposts 365-414--Surficial deposits probably averaging 10 feet in thickness underlie rolling or ridged moraine. Ice-bearing glacial diamicton predominates over ice-contact (Mileposts 373, 374, and 376) and glaciolacustrine deposits (Milepost 375); bedrock is exposed locally.

Mileposts 414-420--Ice-rich clay and silt deposited in a glacial lake.

Mileposts 420-456--Ice-bearing sand and silt that were deposited as beaches and deltas of a large glacial lake. The sand and silt, which may average 10 feet in thickness, are locally overlain by ice-rich organic material averaging 3 feet in thickness.

Mileposts 456-565--Ice-rich clay, silt, and sand that were laid down in a glacial lake. They probably average 20 feet or more in thickness and are locally overlain by postglacial alluvial fan deposits. Sand and gravel that may represent buried deltas occur at Mileposts 503, 506 to 509, 548, 551 to 552, and 553 to 555.

Mileposts 565-576--Ice-rich sand, silt, and some gravel that probably average 15 feet in thickness. Deposits were formed as beaches and deltas of the large glacial lake first described at Milepost 340.

Mileposts 576-590--Rolling to ridged moraine underlain by glacial diamicton averaging 15 feet in thickness. Between Mileposts 580 and 586, ice-rich glaciolacustrine deposits of clay, silt, and sand are present. Locally, bedrock is exposed.

Mileposts 590-601--Thin to very thin deposits of glacial drift overlying bedrock at shallow depth. Some ice-rich sand in the form of deltaic deposits probably is present between Mileposts 595 and 597.

Mileposts 601-645--Rolling to hummocky moraines of permanently frozen glacial diamicton which may have a maximum thickness of about 30 feet near Milepost 621. The diamicton is covered by a mixture, as much as 15 feet thick, of wet organic silt and some sand that may have a relatively high ice content. Between Mileposts 617 and 626 the diamicton is covered by wet deposits of peat that may average 6 feet in thickness and contain considerable ice. Between Mileposts 642 and 645, diamicton is thin to very thin and overlies bedrock.

Mileposts 645-670--Ice-rich silty clay; wet peat that may have an average thickness of 6 feet mantles clay in most places.

Mileposts 670-683--Lacustrine, ice-rich, silty clay; and permanently frozen diamicton, probably with a high silt and clay content, forming rolling to hummocky moraine. Locally, permanently frozen organic materials cover the lacustrine deposits; near Milepost 678 are minor alluvial deposits of organic sand with probably some gravel.

Mileposts 683-723--Deltaic, ice-rich, fine to coarse sand deposits with some pebble gravel. In most places organic deposits, many of which may be permanently frozen, cover the sand. Sand dunes exist locally between Mileposts 689 and 699 and between 703 and 706. Organic silt-mantled alluvium of sand and some gravel is present near Mileposts 714, 717, and 722. Minor amounts of diamicton in hummocky moraines are present between Mileposts 714 and 716.

Mileposts 723-737--Gently rolling to hummocky moraines of probably silt- and clay-rich diamicton; in many places the upper several feet is loose, gravelly sand. Commonly, the moraine is covered by a mantle of wet organic material that may average 6 feet in thickness and may be permanently frozen.

Mileposts 737-805--Gently rolling to hummocky and linear moraines probably composed of permanently frozen silt- and clay-rich diamicton. Commonly the upper several feet is a loose gravelly sand that in some places is in the form of eskers or crevasse filling. Many areas have as much as 6 feet of overlying wet organic deposits, many deposits of which may be frozen. Near Mileposts 770 and 771 and between Mileposts 774 and 784, bedrock may be present within several feet of the ground surface. Organic silt-mantled alluvium of sand and (or) gravel is present near Mileposts 747, 752, 758, 760, and 804; those deposits near 747 probably have the largest percentage of gravel.

Mileposts 805-821--Gently rolling to hummocky to linear moraines probably composed of silt- and clay-rich diamicton. Some diamicton is permanently frozen. Commonly, the moraines are covered by a mantle of wet organic material, some of which may average 6 feet in thickness and may be permanently frozen.

South of 60° N Latitude

Surficial deposits of many types are present in the general area of the proposed route (Figure 2.1.2.3-6). Listed in decreasing order of abundance, they are: (1) sediments deposited by the last major glaciation, (2) products of postglacial weathering and accumulation processes, (3) deposits of earlier glaciations, and (4) frost-shattered rock fragments on unglaciated bedrock.

During the maximum extent of the last major glaciation, almost all of western Canada was covered by the Laurentide Continental Ice Sheet or by valley glaciers of the Rocky and Columbia Mountains (Prest, 1970). Only a few areas in southern Saskatchewan and Alberta were not glaciated. Deglaciation was largely complete by 14,000 to 15,000 years ago in southern Saskatchewan and southern and central Alberta, but in northwestern Alberta and in lower mountain valleys of Alberta and southeastern British Columbia deglaciation did not occur until about 11,000 years ago.

Glacial deposits and deposits associated with glaciers in the general area of the proposed pipeline include: (1) glacial diamicton (till), consisting of sand and gravel in a matrix of silt and clay; diamicton commonly forms hummocky or smooth ground moraines; (2) sand and gravel deposited in glacial rivers, deltas, fans, beaches, and within and around glacier ice (ice-contact deposits); (3) sand and silt in wind-dominated areas; and (4) silt and clay of former lakes and dune fields. Glacial deposits are coarser grained in mountainous areas than in the plains region of Alberta and Saskatchewan.

In postglacial time, the glacial deposits were modified by running water, freezing and thawing, mass wasting, and wind. In northern Alberta, postglacial modifications also included accumulation of peat and development and partial degradation of permafrost.

The following postglacial deposits are especially prevalent along the proposed route south of 60° N latitude: (1) alluvial sand, gravel, and silt; (2) colluvial sediments ranging from organic silt to coarse bedrock rubble; (3) windblown sand and silt; and (4) peat. In mountainous areas, postglacial deposits are coarser than in the plains regions.

In the following descriptions of surficial deposits along the proposed pipeline, linear segments with similar sediments are identified by the route mileposts. The descriptions are generalized from many different reports, including: Canadian Arctic Gas Pipeline Ltd. (1974a, b, d, e), Government of Alberta (1969), Henderson (1959), Johnston and others (1948), Lindsay and others (1958, 1959, 1960), Pawluk and Bayrock (1969), Prest and others (1968), Price (1962), Richards and Fung (1969), Roed (1970), Stalker (1962, 1965, 1973), and St. Onge (1967).

Main Line

Mileposts 821-878--Gently rolling to slightly hummocky to uniformly sloping moraine, consisting of glacial diamicton at least 30 feet thick and containing a high percentage of silt and clay. Frozen organic deposits probably cover the diamicton along nearly half of this segment of the route. The mantle may vary from 3 to 20 feet in thickness. Some postglacial alluvial deposits, probably consisting of organic silt-mantled coarse sand and (or) gravel, are present near Mileposts 824, 840, and 851.

Mileposts 878-947--Glaciolacustrine clay and silt with possibly some sand. Locally, organic deposits are abundant, especially from Milepost 899 to 908, where about half of the glaciolacustrine deposits are covered by organic materials. Maximum thickness of organic deposits may be as much as 30 feet; some deposits are perennially frozen.

Mileposts 947-958--Gently rolling to uniformly sloping ground moraine consisting of glacial diamicton containing a high percentage of silt and clay. Organic deposits, some of which may be frozen, cover part of the diamicton.

Mileposts 958-982--Glaciolacustrine clay, silt, and probably some sand; materials may be at least 20 feet thick. Locally, organic deposits occur, probably few of which are permanently frozen. An area of postglacial alluvium occurs near the Chinchaga River crossing (Milepost 970).

Mileposts 982-1011--Gently rolling to hilly ground moraine composed of diamicton of glacial origin with a high percentage of clay and silt. Some of the clays are probably bentonitic. Diamicton in many areas is mantled by glaciolacustrine clay and silt that may be as much as 30 feet thick. Some postglacial alluvial sand present locally, especially near the Botha River crossing (Milepost 1002).

Mileposts 1011-1020--Thin glaciolacustrine clay and silt deposits commonly mixed with glacial diamicton which contains as much as 80 percent clay and silt. Some of the clays are probably bentonitic. Organic deposits, possibly as much as 10 feet thick, locally cover the clay and silt. A few of the organic deposits may be perennially frozen.

Mileposts 1020-1042--Gently rolling to hilly ground moraine of glacial diamicton containing as much as about 80 percent clay and silt. In many areas, the diamicton is irregularly mantled by glaciolacustrine clay and silt as much as 30 feet thick. Sand and some gravel may be present in former glacial melt-water drainageways, and near the Hotchkiss River crossing (Milepost 1027). Areas of organic deposits as much as 1 mile in maximum dimension cover other surficial deposits.

Mileposts 1042-1077--Glaciolacustrine clay and silt, in some places underlain by clay- and silt-rich diamicton of glacial origin. The lacustrine sediments may be as much as 30 feet thick. Organic deposits, some of which may be perennially frozen, occur between Mileposts 1047 and 1052, and between 1061 and 1066.. Areas predominantly of glacial diamicton having a high content of clay and silt are between Mileposts 1058 and 1061 and near Milepost 1068. Sand probably is present in postglacial alluvial deposits near the Notikewin River crossing (Milepost 1043) and Whitemud River crossing (Milepost 1071).

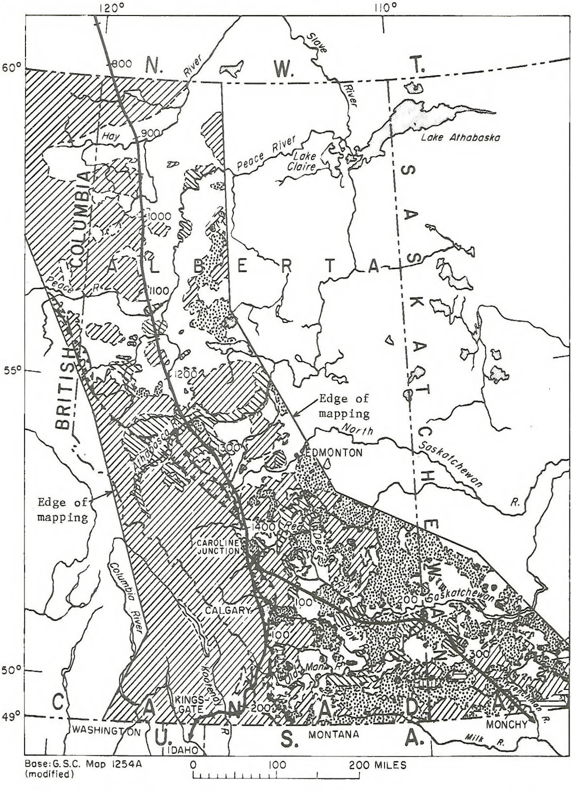


Figure 2.1.2.3-6 Surficial deposits in the region of the proposed route south of 60° N latitude

EXPLANATION

Deposits are of Wisconsin (last glacial) age except as noted.

□	Chiefly lacustrine deposits: silt, clay, and some sand. In part early postglacial in age
▧	Chiefly alluvial deposits: sand and/or gravel; commonly dune covered. Includes outwash plains, valley trains, and deltas. In part postglacial in age
▨	Mainly smooth to gently rolling ground moraine plains of variably stony diamicton (till) having a fine-grained matrix. Includes alluvial deposits, some of which are postglacial in age
░	Principally hummocky moraine of stony diamicton (till). Includes complexes of end, lateral, and kame moraines. In part pre-Wisconsin in age
▤	Mostly ground moraine of variably stony diamicton (till) of pre-Wisconsin age. Includes some thin and patchy deposits in unglaciated areas
▥	Thin and patchy deposits in unglaciated areas: (1) rubble developed from in-place weathering of bedrock, (2) colluvium of variable texture, and (3) wind-transported silt and sand. Pre-Wisconsin and younger in age

SYMBOLS

—┼—	Milepost for proposed pipeline
– – – –	Contact between map units
⊥⊥ ⊥ ⊥⊥	Outer limit of Wisconsin (last) Laurentide continental ice sheet; ticks on glacier side of line
▲▲ ▲ ▲▲	Outer limit of Wisconsin (last) Cordilleran ice sheet; ticks on glacier side of line

Mileposts 1077-1088--Rolling ground moraine composed of glacial diamicton with as much as 80 percent clay and silt. Thickness of diamicton locally may be less than 10 feet. There probably are a few thin organic deposits.

Mileposts 1088-1108.5--Predominantly postglacial sand that was worked by wind into dune forms. In some of the depressions between hillocks of sand, small thin deposits of organic materials are probably present. The source of the sand was late-glacial alluvial outwash of the ancestral Peace River; some alluvium is probably exposed along this segment of the proposed route. Underlying the dune and alluvial materials at depths of as much as 15 feet are deposits of glaciolacustrine silt and clay. The lacustrine materials are probably exposed between Mileposts 1088 and 1092.

Mileposts 1108.5-1113--Possible multiple landslides of several different ages where the route descends the north valley wall for about 800 feet vertically to the crossing of the Peace River. The ascent of the proposed route on the south valley wall is steeper than the descent on the north side, and there is less evidence of landslides. Geologic materials comprising the possible landslides probably consist of: (1) glaciolacustrine silt and clay, (2) glacial diamicton with a very high content of silt and clay, and (3) shale dipping south or southwest toward the river. A small area of probably gravelly alluvium lies on the valley floor adjacent to the north side of the Peace River.

Mileposts 1113-1147--Dune sands averaging 15 feet in thickness. The source of the sand was late-glacial alluvial outwash related to the ancestral Peace and Smoky Rivers. A few areas of alluvium are exposed near Milepost 1146. Underlying the alluvium and dune sand is glaciolacustrine silt, some of which is exposed between Mileposts 1117 and 1125. Numerous small deposits of organic materials occur within the area. Near the crossing of Smoky River (Milepost 1141) and for several miles to the north, landslide deposits of silt, clay, or shale bedrock may be present along or near the proposed route.

Mileposts 1147-1171--Rolling to hummocky ground moraine composed of glacial diamicton rich in silt and clay and averaging 15 feet in thickness. At several places between Mileposts 1164 and 1168, and, locally elsewhere, bedrock may be exposed. Glaciofluvial deposits of sand and gravel are near Milepost 1158. Some organic deposits occur, and these are as much as half a mile in maximum dimension. A thin mantle of silt may overlie the diamicton deposits.

Mileposts 1171-1232--Glaciolacustrine silt and clay overlying diamicton. Organic deposits as much as 15 feet thick locally cover the lake sediments, especially near Mileposts 1195, 1197, 1198-1199, 1204, and 1213, possibly between Mileposts 1218 and 1220, and near Milepost 1224. An area of gently rolling ground moraine consisting of glacial diamicton with a high percentage of silt and clay is between Mileposts 1180 and 1184. Fine-grained postglacial alluvial sand, some gravel, and some silt may be present between Mileposts 1190 and 1195 near the Little Smoky River crossing and near the Iosegun River crossing (Mileposts 1205-1207).

Mileposts 1232-1247--Rolling ground moraine underlain by as much as 50 feet of moderately stony glacial diamicton with as much as about 80 percent silt and clay. The expansive clay mineral montmorillonite constitutes 55 percent of some samples of the clay-size fraction of the diamicton matrix. Hummocky moraine occurs locally.

Mileposts 1247-1251--Glaciodeltaic and postglacial fluvial deposits ranging from sand and coarse gravel to silt. The crossing of the Athabasca River would occur in this segment.

Mileposts 1251-1275--Hummocky moraine of moderately to very stony diamicton high in silt and clay and averaging 15 feet in thickness. Bedrock may be exposed locally between Mileposts 1256 and 1263. Organic deposits of variable thickness overlie diamicton along the proposed route, especially between Mileposts 1264 and 1266, near Milepost 1270, and between Mileposts 1274 and 1275. At the Pine Creek crossing (Milepost 1255), thin alluvium and colluvium of sand, silt, and gravel form the valley walls; bedrock may be exposed locally.

Mileposts 1275-1290--Rolling ground moraine of diamicton containing few stones and a high percentage of silt and clay. The clay-size fraction of some samples may contain about 45 percent of the expanding clay mineral montmorillonite. Deposits are probably at least 15 feet thick. At several places (Mileposts 1279-1284, and 1786-1788) the diamicton is overlain by as much as 10 feet of glaciolacustrine clay, silt, and sand. Postglacial organic deposits are associated with some of the glaciolacustrine deposits.

Mileposts 1290-1292--Postglacial alluvium of gravel and sand deposited by the McLeod River.

Mileposts 1292-1308--Fine sand, forming stabilized, vegetated dunes. Locally, there are organic deposits between the dunes, especially between Mileposts 1306 and 1308.

Mileposts 1308-1325--Glaciolacustrine silt and clay locally overlain by patches of organic deposits, some of which are as much as half a mile in maximum dimension (Milepost 1317, Mileposts 1320-1321).

Mileposts 1325-1335--Gently rolling ground moraine composed of glacial diamicton containing a high percentage of silt and clay. Organic deposits probably are abundant between Mileposts 1327 and 1328.

Mileposts 1335-1366--Glaciolacustrine silt, clay, and sand averaging possibly 15 feet in thickness. Colluvial deposits, probably derived from glaciolacustrine and glacial diamicton, may occur along steep river bluffs near the crossings of Pembina River (Mileposts 1339-1342) and North Saskatchewan River (Mileposts 1349-1352). Two large areas of organic deposits are located between Mileposts 1360 and 1363 and 1364 and 1366.

Mileposts 1366-1390--Hilly ground moraine composed of diamicton with a high percentage of silt and clay. Bedrock may be exposed locally, especially between Mileposts 1375 and 1385. Organic deposits are numerous, small, and probably only several feet thick.

Mileposts 1390-1423--Several feet of lacustrine silt and clay of glacial and probably postglacial age overlying glacial outwash sand and gravel. Similar outwash sand and gravel occur at the surface at places along the proposed alinement between Mileposts 1410 and 1420. Organic deposits are common, especially near Mileposts 1392, 1393, 1397, 1401, 1405, 1407, and 1409.

Mileposts 1423-1430--Very hummocky moraine probably composed of stony diamicton with a high percentage of silt and clay. Organic deposits are very common, small, and probably average less than 10 feet in thickness.

Monchy Delivery Line

Mileposts 0-24--Gently rolling ground moraine of glacial diamicton having a moderately high percentage of silt and clay. Some extensive areas of postglacial alluvial and glaciofluvial gravel and sand occur near the James River crossing (Mileposts 1-2), Red Deer River crossing (Mileposts 8-10), Eagle Creek-Little Red Deer River crossing (Mileposts 14-16), and possibly near Milepost 20. Adjacent to the crossings, a mantle of sand and silt as much as 5 feet thick may be present.

Mileposts 24-33--Glaciolacustrine deposits of silt, clay, and, locally, sand. The lake deposits overlie glacial diamicton at depths of possibly 10 feet. Thin organic deposits probably exist in some places.

Mileposts 33-65--Gently rolling ground moraine composed of glacial diamicton rich in silt and clay and probably as much as 50 feet thick in most places. The diamicton is overlain by a few feet of sand and silt near the rim of stream valleys such as Carstairs Creek and Rosebud River. Some thin postglacial alluvial sand and gravel may be present along the floors of Carstairs Creek (Mileposts 38-39) and Rosebud River (Mileposts 56-57).

Mileposts 65-93--Sandy to clayey lacustrine deposits of late glacial and early postglacial age. The more clayey sediments are between Mileposts 86 and 92. Some glacial diamicton deposits are between Mileposts 82 and 84; sandy to silty alluvium is present near the crossings of Rosebud River (Milepost 73) and Serviceberry Creek (Milepost 87). The total thickness of surficial deposits is as much as 100 feet.

Mileposts 93-131--Hummocky to gently rolling ground and recessional moraines composed of a variety of sediments, including: (1) glacial diamicton with moderately high percentages of silt and clay, and (2) minor amounts of glacial ice-contact sand, silt, and gravel. Analysis of samples of the clay-size fraction of the diamicton indicates an average of 40 percent montmorillonite, a swelling clay mineral. Total thickness of surficial deposits varies from a few inches to 100 feet; locally, bedrock is exposed near Mileposts 94, 97, and 100.

Mileposts 131-136--Lacustrine silt, sand, and clay that probably overlie glacial diamicton at depths of less than 20 feet. Total thickness of surficial deposits may be as much as 90 feet. The lake sediments were deposited in late glacial and early postglacial time.

Mileposts 136-151--Dunes composed mostly of sand and silt. Glacial outwash underlies the dunes at depths averaging probably 10 feet. Some lacustrine deposits, partly of glacial age, are between Mileposts 143 and 146.

Mileposts 151-215--Generally smooth ground-moraine plain between Mileposts 151 and 173 and hummocky to very hummocky moraine between Mileposts 173 and 215. Surficial deposits are mostly glacial diamicton with a high percentage of silt and clay. Samples of the clay-size fraction contain an average of 45 percent montmorillonite. The deposits may average 20 feet in thickness; locally, bedrock is exposed at least near stream crossings such as the Matzhiwin River (Mileposts 151 and 153), Rishman Creek Coulee (Milepost 167), and Wolf Creek Coulee (Milepost 172). Other types of glacial drift that are locally extensive probably include: (1) ice-contact deposits of sand, gravel, and some silt; (2) glaciofluvial deposits of sand and gravel; and (3) lake deposits ranging from clay and silt to sand. The area of small lakes between Mileposts 183 and 191 probably contains lake sediments that were in part deposited during postglacial time.

Mileposts 215-227--Dune sand, which is as much as 20 feet thick. The source of the sand was the outwash deposits transported by the ancestral South Saskatchewan River during glacial and early post-glacial times.

Mileposts 227-230--Ancestral channels and the steep to gently inclined valley walls of the South Saskatchewan River (Milepost 228). Where the proposed line would have the steepest gradients--within 500 feet of the river--thin colluvial deposits of silt and clay are probably present and landslide deposits may exist; some bedrock is probably exposed in places. The ancestral river channels and terraces contain glaciofluvial and some postglacial sand and gravel that locally may be as much as 20 feet thick. Beneath the sand and gravel is diamicton having a moderately high percentage of silt and clay. Accumulations of windblown sand and silt may occur on the upland surface near both valley rims.

Mileposts 230-239--Glaciolacustrine sand and silt as much as 15 feet thick. Dune sand deposits may occur between Mileposts 232 and 234.

Mileposts 239-274--Hummocky to smooth ground moraine composed of diamicton averaging 20 feet in thickness and probably containing a high percentage of silt and clay. The route crosses lake deposits, most of which are postglacial in age, near Mileposts 251, 253, 257, and 259. These sediments are typically clay and silt, probably less than 10 feet thick. Glaciolacustrine deposits of sand and silt occur between Mileposts 263 and 273. These coarser lake deposits are shore-face sediments formed in a large glacial lake centered to the northeast of the alinement of the proposed pipeline.

Mileposts 274-296--Mostly dune sand.

Mileposts 296-308--Glaciolacustrine deposits of sand, silt, and clay overlying diamicton at variable depths. The maximum thickness of the lake sediments may be 10 feet. Some diamicton is exposed in an area of hummocky moraine between Mileposts 301 and 306.

Mileposts 308-310--The lower, gentler part of the ascent to the Cypress Hills plateau (Figure 2.1.2.3-2) is probably across postglacial alluvial sand and silt several feet thick; the alluvium overlies lake deposits, which in turn overlie diamicton. The upper, steeper part of the ascent is probably across thick, silty colluvium, landslide deposits, and thin glacial diamicton. Bedrock is probably exposed locally.

Mileposts 310-336--Gently rolling ground moraine of diamicton possibly as much as 15 feet thick. The crossing of Bone Creek valley (Mileposts 313-314) is steep and probably in bedrock thinly veneered by surficial deposits, including silty colluvium of possible landslide origin. Glacial diamicton between Mileposts 310 and 315 is probably stonier than that between Mileposts 315 and 336, which has a higher percentage of silt and clay.

Mileposts 336-350--Diamicton, with a moderately high percentage of silt and clay. The diamicton forms hummocky moraines of low relief between Mileposts 336 and 343 and smooth moraine plains between Mileposts 343 and 350. The diamicton probably averages less than 15 feet in thickness.

Mileposts 350-360--Bedrock is probably exposed along much of the alinement, although some thin surficial deposits are present that are related to the valley floor and the broad, gently sloping valley margins of Frenchman River and its tributaries. Deposits include: (1) thick, silty colluvium, probably including some landslide debris; (2) glacial diamicton with a moderately high silt and clay content, especially between Mileposts 352 and 354; and (3) fine-grained postglacial alluvial silt and sand along the low terraces and present flood plain of Frenchman River.

Mileposts 360-394--Low-relief, hummocky moraine, consisting of glacial diamicton with a high percentage of silt and clay. Locally, there probably are glacial ice-contact sand, gravel, and silt. Total thickness of surficial deposits is probably less than 15 feet.

Kingsgate Delivery Line

Mileposts 0-20--(1) Glaciolacustrine silt and clay, (2) glacial diamicton in moraines, and (3) alluvial sand and gravel of glacial and postglacial age. The alluvial materials are exposed at the crossings of James River (Milepost 1) and Red Deer River (Mileposts 10-13); they overlie diamicton and may be as thick as 15 feet. Glaciolacustrine deposits are present between Mileposts 2 and 6, and probably locally near Milepost 20; they overlie diamicton and may be less than 10 feet thick.

Mileposts 20-51--Gently rolling to nearly flat ground moraine composed of glacial diamicton and probably some glaciofluvial deposits. Postglacial alluvium is probably present in small quantities.

Mileposts 51-114--Glacial deposits predominate and may average 10 feet in thickness. Deposits probably are equally divided among the following: (1) diamicton, mostly in ground moraine; (2) gravel and sand in abandoned glacial stream channels and glacial ice-contact landforms; and (3) silt and clay deposited in glacial lakes. Postglacial alluvial deposits are prominent near crossings of the Bow River (Milepost 55), Elbow River (Milepost 66), Threepoint Creek (Milepost 86), and Highwood River (Milepost

100). Windblown sand and silt probably are locally abundant near these and other streams.

Mileposts 114-136--Glacial and nonglacial deposits. Deposits probably average 10 feet in thickness; in many places bedrock is exposed. Glacial deposits probably consist of diamicton and some glacial stream gravel. The nonglacial deposits include: (1) postglacial alluvial coarse to fine gravel, sand, and silt; (2) colluvial and alluvial deposits derived from bedrock slopes adjacent to the route; and (3) some wind-deposited sand and silt.

Mileposts 136-138--Bedrock crossing of a steep mountain ridge in the Livingstone Range.

Mileposts 138-147--Mostly bedrock with locally a veneer of drift or colluvial silt, organic silt, and bedrock rubble. Some alluvial coarse gravel and alluvial sand on the floor of White Creek valley and tributaries.

Mileposts 147-152--A several-foot-thick veneer of colluvial silty bedrock rubble or glacial drift over bedrock. Thicker deposits may be present near the crossing of Oldman River (Milepost 148), where there probably are alluvial deposits of gravel and sand at least 20 feet thick.

Mileposts 152-153--Alluvial gravel and sand deposits along the north margin of the floor of Dutch Creek valley where the floor meets the steep north wall. Some colluvial deposits may be present, a few of which probably are very coarse bedrock rubble.

Mileposts 153-158--Mostly bedrock with some colluvial deposits of very silty rubble and possibly some glacial deposits and minor alluvium as a veneer a few feet thick over bedrock.

Mileposts 158-163--This segment ascends the valley of South Racehorse Creek, where thin deposits of colluvium and some glacial deposits and alluvium are probably present along the narrow valley floor and lower slopes of the valley margin.

Mileposts 163-167--The proposed route crosses the Crowsnest Mountain divide from South Racehorse Creek to Allison Creek. Surficial deposits are patchy in occurrence, probably less than 5 feet in thickness between bedrock outcrops, and consist of colluvial silty rubble.

Mileposts 167-174--Colluvial very silty rubble, glacial deposits, and postglacial alluvial gravel. The alluvial material occurs in large fans, some of which bear streams that carry large quantities of rock fragments during floods.

Mileposts 174-181--Mostly bedrock, covered in places by colluvial rubble and glacial deposits. Some glaciofluvial and postglacial gravels probably occur near the Summit Creek crossing (Milepost 179).

Mileposts 181-195--Mostly colluvial silty rubble that may be as much as 10 feet thick near the valley walls of Michel and Leach Creeks. Postglacial alluvial gravel and sand as much as 20 feet thick probably exist near the crossings of Michel Creek (Milepost 185) and Leach Creek (Mileposts 189 and 194).

Mileposts 195-209--Crossing of the steep mountain divide of Flathead Ridge, where surficial deposits are insignificant in quantity. Some patches of alluvium are present near Mileposts 197 and 208.

Mileposts 209-215--Alluvial gravel related to active erosion and deposition in Lodgepole Creek and Wigwam River. Small alluvial fans and rubbly colluvial deposits may be concealed by the gravels of Lodgepole Creek and Wigwam River.

Mileposts 215-231--Several types of surficial deposits of variable thickness; possibly the most prevalent ones are silty to sandy colluvial rubble and glacial deposits, from Mileposts 216 to 218, 224 to 228, and 229 to 230. Deposits are probably less than 5 feet thick. Some glaciofluvial deposits as much as 30 feet thick occur between Mileposts 219 and 223; some postglacial gravel and sand are present near the crossings of Elk River (Mileposts 218-219), Big Sand Creek (Milepost 229), and Kootenay River (Milepost 231, Figure 2.1.2.2-31).

Mileposts 231-239--Mostly bedrock, except near Gold Creek crossing (Milepost 236), where gravelly alluvium less than 10 feet thick may be present.

Mileposts 239-248--Mostly bedrock, except near the mouths of the small valleys tributary to Tepee Creek, where there probably are thin deposits of colluvial silty to sandy bedrock rubble, various glacial materials, and alluvial fan gravels.

Mileposts 248-255--Probably only bedrock is present on this crossing of the ridge crest of the Yahk Range.

Mileposts 255-274--Alluvium and colluvium of the floor and lower slopes, respectively, of the Moyie River valley. The major types of alluvium are gravel and sand of the present flood plain and glaciofluvial terrace gravels which are at least several dozens of feet above the present river. Alluvial deposits are probably less than 30 feet thick. Streams tributary to Moyie River have alluvial fan gravels less than 20 feet thick along the outer part of the floor of the Moyie valley. Colluvium probably is patchy in occurrence, and consists of a mixture of bedrock rubble and materials of glacial origin. Between Milepost 262 and 263, the proposed pipeline is routed onto bedrock slopes to heights of several hundreds of feet above river level.

Mileposts 274-281--Colluvium and alluvium, in nearly equal quantities, related to the floor and margin of Moyie River valley. Colluvium is thin and patchy between bedrock outcrops and is probably composed of bedrock rubble, and, locally, diamicton. Alluvial gravels form the present flood plain and terraces of the Moyie River. Most of the terraces originated during glacial times, although some may be of postglacial age. Most alluvial deposits probably are less than 30 feet thick.

Mineral Resources

Metallic and Nonmetallic Minerals

No metallic or nonmetallic mineral resources (other than fuels) with historic production great enough (36,000 tons) to be plotted on Map 1252 A, Mineral deposits of Canada (Douglas, 1970), are within 150 miles of the proposed route except in southeastern British Columbia. One of these British Columbia deposits originally contained an estimated 1 million to 15 million tons of material potentially valuable for lead, silver, zinc, and gold. Nearby is a gypsum deposit estimated at less than 1 million tons.

According to data submitted by the Applicant, there is prospecting activity in the Wrigley-Fort Norman area on both sides of the Mackenzie River. The interest is mainly in lead-zinc occurrences. In Alberta the proposed route is near low-grade oolitic iron deposits and within 15 miles of nonmetallic and industrial mineral deposits, including bentonite, cement materials, pumicite, gypsum, and salt. In southwestern Saskatchewan there are sodium sulfate and clay deposits within a few miles of the route of the proposed Monchy Delivery Line.

Sand and gravel are common throughout the area traversed by the proposed route, but locally these commodities may be scarce.

In the southern Rocky Mountains and Foothills near the boundary between British Columbia and Alberta bituminous (locally semianthracite) coal occurs, mainly in the Lower Cretaceous Kootenay Formation. Greatest development of coal is in the Crowsnest coalfield in southeastern British Columbia and in the valley of the Bow River west of Calgary, Alberta (Little and others, 1970, p. 523-524). (In material submitted by the Applicant the Crowsnest coalfield is referred to only as part of the Fernie coal basin.) Undeveloped coal beds near the proposed route are known to occur in the vicinity of Fort Norman, N.W.T. (Little and others, 1970, p. 523-524). Large areas of the plains of southern Alberta and parts of Saskatchewan are underlain by Upper Cretaceous and Tertiary subbituminous coal and lignite (Little and others, 1970, p. 523-524). Most of the route of the proposed Monchy Delivery Line would be through undeveloped parts of these areas.

Oil and Gas

North of 60° N latitude the proposed pipeline passes within about 150 miles of most or all of seven sedimentary basins Old Crow, Eagle, Mackenzie, Peel, Anderson, Banks, and Tathlina. The route also lies 750 miles south of the center of the sedimentary basin of the Arctic Islands. These sedimentary basins are prospective oil and gas provinces (McCrossan and Porter, 1973).

South of 60° N latitude the proposed route traverses the length of the Alberta-British Columbia oil and gas province. Exploration drilling has attained a density of one well per 21 square miles in the prospected parts of this province, and has resulted in production amounting to 5.5 billion barrels (Bb) of oil and 14 trillion cubic feet (Tcf) of gas; reserves are estimated at 6 Bb oil and 55 Tcf gas (McCrossan and Porter, 1973, p. 711 and 716).

The basins north of 60° N latitude have been little explored, but they contain significant thicknesses of sedimentary rocks resembling strata that elsewhere contain deposits of oil and gas. Even at the present relatively low level of exploration, reserves and resources of hydrocarbons are known in three of the basins: Mackenzie, Anderson, and Tathlina.

Initial exploration in and near the Mackenzie Delta basin resulted in the discovery of four oil fields and seven gas fields (Oil and Gas Journal, February 4, 1974, p. 25), and identified resources estimated at 15 Tcf gas and less than 2 Bb oil (Rudkin, 1974, p. 148). However, more recent estimates (Oil and Gas Journal, April 1, 1974, p. 36 and Oil and Gas Journal October 7, 1974, Newsletter p. 3) downgrade the gas resources to 7 Tcf. Meanwhile, exploration has extended to the shallow offshore areas where the subsurface thickness of prospective rocks is greater. There the second of three wildcat wells discovered gas; 10 more exploratory wells are drilling or planned (Oil and Gas Journal, July 7, 1974, p. 24). The Applicant's most recent estimate of proven reserves for the Mackenzie Delta area (prepared by Sproule Associates Limited in December, 1974) is 3.9 Tcf (CAGPL, 1975nb, p. 2).

In the Anderson basin oil in the Norman Wells Field has no associated gas (Gilbert, 1973, p. 215). In the Tathlina basin reserves in two gas fields southwest of Fort Simpson total 3.7 Tcf (de Wit and others, 1973, p. 204), and the gas is being recovered through the Westcoast Transmission Company pipeline.

The amounts of potentially recoverable gas in these immaturely explored basins cannot be forecast with assurance. MacKay and North (1974) doubt the applicability of estimating productivity by the "analogous-volume-of-rock" method unless estimates incorporate probability factors. They are also skeptical of calculations of gas potential based on estimated oil in place. There seems no alternative to the volumetric method for assessing potential reserves in excess of proven reserves in individual basins.

A recent evaluation of Canada's future petroleum provinces (McCrossan and Porter, 1973) takes into account more than just the volume of rock involved and provides the best guess for the magnitude and probability of the eventual gas yield from the immaturely explored basins. This information is repeated in Table 2.1.2.3-1; more recent but apparently less constrained estimates (Rudkin, 1974a, b) are given where applicable. Though the Whitehorse and Bowser basins lie outside the corridor of the proposed route, they have been included because of their relevance to alternative routes. These two unexplored basins do not significantly affect the potentials of the basins within the corridor of the proposed route, however. The calculated average yield from the aggregate potential of frontier basins in the north compares conservatively to the average yield from the maturely explored province to the south.

The northern potentials will attract testing as feasibility permits and as long as promise holds out. The volumes of gas found probably will put ultimate recovery within the order-of-magnitude between the 10.7 Tcf identified and the 106 Tcf sum of the potentials listed in Table 2.1.2.3-1. The eventual yield may well be more than double the current identified figure. Realization of the probable potential of the offshore Mackenzie and Banks basins would multiply the figure several fold but would still leave the ultimate recovery less than 106 Tcf.

About two-thirds of the potential south of 60° N latitude has been discovered (McCrossan and Porter, 1973, p. 712) and most of the remaining third probably will be discovered at a slower pace. Moreover, the increase in real value of petroleum will add to the ultimate yields through

Table 2.1.2.3-1 Attributes of sedimentary basins or provinces related to proposed route

No.	Sedimentary basin or province (type)	Potential ultimate recoverable gas-trillion cu. ft. (oil-billion bbl.)	Identified gas (oil)	Exploration maturity	Qualitative rating for gas (for oil)	Frequency, size of potential accumulations	Volume of sedimentary rock
1	Mackenzie (unstable coastal margin)	64 Tcf (8 Bb)	7 Tcf(1) 15 Tcf(2) (<<2 Bb(2))	Low; moderate in delta (>50 wells)	Good to excellent	Numerous moderate; possible giants	>100,000 mi^3
2	Banks (unstable coastal margin)	11.4 Tcf (1.9 Bb)	Nil	Low; nil offshore	Fair on land; good offshore	Numerous moderate; possible giants	38,000 mi^3
	No. 1 and No. 2(2)	100 Tcf (12 Bb)					130,000 mi^3
3	Old Crow (craton margin disturbed)	0.072 Tcf (.014 Bd)	Nil	Nil	Poor	Few small to moderate	2,900 mi^3
4	Eagle (craton margin disturbed)	5.3 Tcf (0.89 Bb)	Nil	Low (1 well/500 mi^2)	Fair	Possible moderate	34,400 mi^2

Table 2.1.2.3-1 (Continued)

5	Peel (craton margin)	7.3 Tcf (1.2 Bb)	Nil	Low (1 well/870 mi^2	Fair	Infrequent small; possible giant	60,700 mi^2
6	Anderson (craton center)	1.4 Tcf (1.4 Bb)	(60 MM b)	Low (1 well/263 mi^2 near river; 1 well/8,720 mi^2 away)	Poor; fair locally	Numerous small	114,200 mi^3
7	Tathlina (craton center-east; craton margin-disturbed-west)	11.7 Tcf (1.25 Bb)	3.71 Tcf Nil	Very low to moderate (1 well/263 mi^2 in part)	Poor to fair (very poor)	Numerous small and large	200,000 mi^3
	No. 3-7$^{(2)}$	30 Tcf (7 Bb)					
8	Whitehorse (intermontane)	Unlisted	Nil	Nil	Poor (very poor)	Possible small to moderate	15,000 mi^3
	Bowser (intermontane)	5.0 Tcf (nil)	Nil	Nil (1 non-diagnostic well)	Poor (nil)	Few moderate to large	84,000 mi^3
9	ε No. 1-9	106 Tcf, (14.6 Bb)	10.7 Tcf	(calculated average potential gas - 163 MM cf/mi^3)			649,000 mi^3
	ε No. 1-7$^{(2)}$	130 Tcf, (19 Bb)	(<<2 Bb)	(calculated average potential gas - 236 MM cf/mi^3)			---

Table 2.1.2.3-1 (Continued)

10	British Columbia-Alberta province (craton center, margin and margin-disturbed)	124.2 Tcf (22.3 Bb)	68.8 Tcf (12.5 Bb) Reserve: 55 Tcf (6 Bb)	(calculated average potential gas - 278 MM cf/mi^3)	446,000 mi^3

(1) Oil and Gas Journal, April 1, 1974, p. 36.

(2) Rudkin, 1974.

production of resources that were formerly conditional. Likewise, an increase in real value of petroleum may result in a significant but undetermined increase in the conditional resources in heavy oil in the Athabascan tar sands.

Geologic Hazards

Seismicity

The level of earthquake activity along the route of the proposed pipeline is variable, ranging from a maximum in the vicinity of the Yukon-Northwest Territories boundary to a minimum in Alberta. From the Alaska-Yukon border south to the lower 48 states the route traverses all four seismic risk classifications incorporated in the 1970 revision of the seismic zoning map for Canada (Stevens and Milne, 1973, Figure 1).

Segment	Seismic Zones
Prudhoe Bay Supply Line, Mileposts 195-221	2
Prudhoe Bay Supply Line, Mileposts 221-492	3
Richards Island Supply Line	3
Main Line, Mileposts 126-160	3
Main Line, Mileposts 160-240	2
Main Line, Mileposts 240-740	1
Main Line, Mileposts 740-1430	0
Monchy Delivery Line	0
Kingsgate Delivery Line	0

Seismic risk increases from zone 0 to zone 3. The zoning map is based primarily on historic seismicity and is a gross regionalization of seismic risk for the purpose of a national building code.

The seismic history along the proposed route is short relative to the time over which strains accumulate to produce an earthquake, hence the historic record of seismicity is a limited guide to future seismic risk. Earthquakes of magnitude 6 and larger are potentially destructive, and earthquakes of magnitude 5 may cause local damage. North of 60° N latitude, the seismic history may be complete since the early 1930's for earthquakes as small as magnitude 6 and since the late 1950's or early 1960's for shocks as small as 5 (Stevens and Milne, 1973; Leblanc and Wetmiller, 1974). The historic record is only marginally better for the southern portion of the route.

The two largest historic earthquakes along the route were in the magnitude range 6.25 to 6.5 and occurred in the vicinity of the Yukon-Northwest Territories boundary. The epicenters of the two earthquakes are located within 30 to 40 miles of the route in the eastern Richardson Mountains near Fort McPherson. The accuracy of the epicentral determinations is unknown but may be no better than 60 miles (Leblanc and Wetmiller, 1974). The several maps and catalogs of historic earthquakes in the Canadian Arctic published by the Department of Energy, Mines and Resources in Ottawa, Canada (for references, see Stevens and others, 1973, appendix 2), reveal a persistent concentration of seismicity in the vicinity of the Yukon-Northwest Territories border north of 65° N latitude.

Other areas of known seismicity along the route include the southern end of the Mackenzie Mountains and the adjacent Mackenzie Valley between 62° and 65° N latitudes, and a region along the Alberta-British Columbia border south of 55° N latitude. At least two earthquakes of magnitude 5.0 or greater have been located within 50 miles of the route on the western edge of the Mackenzie Valley since the early 1960's when the Canadian network of seismographs was greatly expanded and when earthquakes as small as magnitude 5.0 became routinely locatable. The uncertainty in the epicentral locations is about 60 miles (Stevens and others, 1973, Table A-8). Earthquakes at least as large as magnitude 4.5 are known to have occurred since the early 1960's in a north-south-trending zone more than 100 miles wide along the Alberta-British Columbia border south of 55° N latitude.

The earthquake potential along the pipeline route may be specified in terms of maximum expectable earthquakes as follows:

Segment	Magnitude
Prudhoe Bay Supply Line, Mileposts 195-285	5.5
Prudhoe Bay Supply Line, Mileposts 285-465	7.0
Prudhoe Bay Supply Line, Mileposts 465-492	5.0
Richards Island Supply Line	5.0
Main Line, Mileposts 126-410	5.0
Main Line, Mileposts 410-655	6.0
Main Line, Mileposts 655-1185	4.5
Main Line, Mileposts 1185-1430	5.5
Monchy Delivery Line	4.5
Kingsgate Delivery Line	5.5

The maximum expectable earthquake is the largest earthquake that on the basis of existing knowledge may reasonably be expected to occur along a specified segment; it everywhere equals or exceeds the largest known historic earthquake. The zonation of the route might be further refined if more complete geologic and geophysical data were available.

Focal depths of earthquakes, although not precisely determined, place the earthquakes in the crust. Accordingly, there is no a priori reason to expect that larger earthquakes along the route will not rupture the surface. At present, no faults with surface expression are known to be active, however, detailed geologic field investigations in regions of high seismicity might reveal evidence for geologically recent movements (Stevens and Milne, 1973). Without knowledge of the seismically active faults along and adjacent to the route, there is no basis for assigning the maximum expectable earthquakes to a specific fault and the occurrence of the maximum expectable earthquake anywhere along the pipeline segment must be considered possible.

Erosion and Slope Stability

The purpose of this section is to present a discussion of surface drainage, erosion, and slope stability. The emphasis here is on the factors which control erosion and mass movement in the variety of environments crossed by the route of the proposed pipeline.

Except as noted, information presented in this section has been drawn from documents submitted by the Applicant to U.S. and Canadian governmental agencies. These documents are listed under "References" at the end of this section of the report. Neither stereo aerial photographs or large-scale topographic maps were available during the preparation of this report.

General Drainage and Erosion

Surface erosion due to running water is virtually negligible over much of the proposed route because of an extensive cover of muskeg and other organic materials. Most erosion is restricted to existing stream valleys, gullies, rills, and very steep slopes or bedrock exposures which lack a cohesive cover of vegetation. Factors which influence erosive processes at specific locations include: (1) vegetation; (2) local topography; (3) microclimatic conditions, including rainfall, snow accumulation, and diurnal temperature fluctuations; (4) nature of surface runoff; (5) composition and texture of the surface regolith; and (6) permafrost conditions. These factors are discussed in other sections of this report. Kathol and McPherson (1974) describe problems of erosion in an area with geological conditions similar to those along the proposed route.

Slope Stability

Mass-movement processes are generally thought to be the major processes responsible for lowering the landscape in arctic regions. Important processes operating along the proposed route include: (1) soil creep, (2) solifluction, (3) mudflows, (4) debris avalanches, and (5) rockfalls and other kinds of landslides.

The type and scale of mass-movement processes which can affect a specific location are determined by: (1) bedrock type, (2) surficial material, (3) slope characteristics, and (4) permafrost conditions. These variables are discussed below.

Bedrock Composition Along the Proposed Route--Slope stability is partly a function of the physical properties of rocks exposed at or near the ground surface and their competence and weathering characteristics. The availability of data sources on engineering aspects of bedrock types varies widely for different segments of the proposed route. North of the 60° N latitude, data supplied for the routing by the Applicant and available from Canadian Government agencies are relatively comprehensive. South of the 60° N latitude, less comprehensive data were supplied by the Applicant.

Approximately 13 percent of the proposed pipeline route north of 60° N latitude has bedrock of varying ages exposed at the surface or at a depth of probably less than 10 feet; the rest of the route is covered with a variety of surficial deposits to a depth of probably 10 feet or more. It is roughly estimated that about 70 percent of the exposed bedrock north of the 60° N latitude is shale, much of which may present slope stability problems.

Nearly all of the bedrock exposed south of the 60° N latitude except on the Kingsgate Delivery Line, consists of interbedded shale and sandstone of Tertiary or Cretaceous age. Much of the shale is of the "overconsolidated" type, contains abundant montmorillonitic clays, and is known to cause slope stability problems (Scott and Brooker, 1968).

The susceptibility to frost action, erosion, and mass movement of certain groups of rock types along the proposed route is described in Table 2.1.2.3-2. Well-cemented sandstone, conglomerate, and carbonate rocks are generally competent, and are not involved in mass-movement processes on most slopes. These and other rock types not likely to be involved in slope failures are omitted from Table 2.1.2.3-2. The areal distribution of rock units, some of which are commonly associated with slope instability, is shown on the bedrock geology map of the proposed route, and the rock units are described in the section on bedrock in this Statement.

Surficial Geologic Units--About 90 percent of the proposed route is underlain by a variety of surficial geologic units (engineering soils) which are unconsolidated. The stability of slopes formed on these deposits is a function of such factors as water or ice content, steepness of slope,

Table 2.1.2.3-2 Some engineering properties of rock units likely to be subject to slope instability

Lithologic unit	Susceptibility to frost action	Susceptibility to erosion	Susceptibility to mass movement
Tertiary silt, sand, gravel conglomerate clay shale and lignite	Moderate to high, depending on texture and coherence	Moderate to high	Silt and clay shale subject to slumping on moderate to very steep slopes.
Upper Cretaceous shale, siltstone, and sandstone	Low (coarse materials) to high for finer materials	Low to Moderate for sandstone, high for shale	Shale and siltstone are characterized by tundra mudflows near small lakes. Mass movement expected in shale (especially bentonitic) on moderate or steeper slopes
Lower Cretaceous shale, siltstone, sandstone, and conglomerate	Moderate where poorly cemented. Can be high in shales	Moderate to high (where shale or unconsolidated)	Shale subject to mass movement on moderate to very steep slopes
Jurassic shale, siltstone, and fine-grained sandstone	Variable, low to high	Low-moderate in sandstone, high in shale	Mass movements expected on stream-cut slopes. Local landslides can be expected, especially in western part of the coastal route
Mississippian-Pennsylvanian limestone, sandstone, and shale	Low to high	Low to moderate	Sandstone and limestone generally competent, but solifluction expected on moderate or steeper slopes in weathered shale

Table 2.1.2.3-2 (Continued)

Lithologic unit	Susceptibility to frost action	Susceptibility to erosion	Susceptibility to mass movement
Upper Devonian, shale, siltstone, and sandstone	Low to moderate	Moderate to high in some units	Solifluction occurs in shale on moderate to very steep slopes. Large-scale slumping can occur where slopes are undercut by rivers. This is especially common in the Redknife and Ft. Simpson Formations
Cambrian-Ordovician-Silurian carbonate rocks and shale	Low for carbonate rocks, high for shale	Low for carbonate rocks, moderate to high for shale	Instability may occur on moderate to very steep slopes underlain by shale

permafrost characteristics, and thickness and distribution of organic materials at the ground surface.

Surficial materials which tend to be unstable on slopes are shown in Table 2.1.2.3-3, along with a description of ground-ice conditions and engineering behavior for each unit. Surficial materials which are generally stable are omitted. The geographic distribution of potentially unstable surficial units is described in the section on surficial deposits.

Slope Angle--Mass-movement processes are directly related to slope angle because gravity provides the driving force to make them operate. Even unconsolidated and incompetent materials will tend to be stable and not move on a relatively flat surface. The tendency for slope failure to occur increases proportionately as slope angles increase.

Slopes along the proposed route are described in the section on topography in this report; they have been divided into a series of classes of slope angles. These classes are shown in Table 2.1.2.2-1. The relationship between slopes in these classes and susceptibility of bedrock and surficial deposits to slope failure is shown in Tables 2.1.2.3-2 and -3. Detailed information on longitudinal slopes is presented by the Applicant on 1:2,400-scale Alignment Sheets. Data concerning slopes transverse to the route are included where it is possible to infer such information from 1:250,000-scale maps of the Canada National Topographic System.

Permafrost Characteristics--Permafrost characteristics are an important factor in controlling mass-movement phenomena in the Canadian Arctic. The general distribution of continuous and discontinuous permafrost zones along the proposed route is shown in Figures 2.1.2.3-7 and -8 in the permafrost section of this statement. Mass movement in permafrost zones is influenced by the ice or water content of surficial materials and the thickness of the active layer.

Mass movement generally does not occur in permafrost zones during winter, when the ground is frozen. During the melting season, the thickness of thawed material (active layer), its water or ice content, and slope angle will determine the type and scale of mass-wasting processes in permafrost zones. Although thin mass movement features are most common, large-scale, deep-seated, rapid mass-movements can develop where there is a combination of high moisture content, a thick active layer, and steep slopes. Permafrost conditions along the proposed route are described in the section on permafrost.

Summary of Factors Controlling Mass Movement--Other factors which affect slope stability include seismic shaking and the liquefaction which may result, and loading of a slope by addition of water. However, the slope stability at a specific location can be predicted by considering the composition of the geologic materials beneath the surface, slope angle, and permafrost or surface-moisture characteristics. Data on these factors presented in other sections of this report and cited in this discussion should allow an evaluation of potential slope instability at specific locations along the proposed route.

A conspicuous example of probable slope instability and mass movement can be seen where the proposed route crosses the Peace River in Alberta, near Milepost 1112 (Figure 2.1.2.2-20). There, southeast-flowing tributaries of the Peace River have cut down as much as 800 feet through Upper Cretaceous shales. The resulting trellis drainage pattern has

Table 2.1.2.3-3 Some engineering properties of surficial deposits which may be subject to slope instability

Unit name	General description	Ground-ice conditions (in permafrost zone)	Susceptibility to slope instability or mass movement
Organic terrain	Peat, fen, muskeg. Commonly covers units described below	Peat may contain as much as 60-80 percent segregated ice	Peat landforms thermokarst topography. Highly compressible when thawed. May supply moisture to units below. May also be a stabilizing influence on underlying units
Silt-clay plains	Mainly lake deposits consisting of clay, silt, and fine sand	Commonly has 10 to 50 percent segregated ice parallel to bedding, but may reach 60 percent by volume	Failure is common along scarps. Poor bearing capacity
Till plains	Till occuring as ground moraine or as a variety of landforms	Locally 5-40 percent segregated ice	Failure is common along scarps. Soil creep and possibly solifluction can occur where drainage is impounded
Colluvium of various types	I Colluvium developed on sandstone and shale	Ice may be present in voids and fractures in northern areas, but may be absent to the south	Shale colluvium on moderate to very steep slopes is highly unstable

Table 2.1.2.3-3 (Continued)

Unit name	General description	Ground-ice conditions (in permafrost zone)	Susceptibility to slope instability or mass movement
	II Various unconsolidated deposits on moderate to steep slopes. May include rock detritus on steep river banks or valley walls	Ground-ice content variable	Rockfalls and superficial debris flows occur on steep slopes. Slumping may occur where the surficial mantle is thick or shale is present

interfluve areas with slopes of 15° to 30° on which there appears to be extensive slumping and landsliding. The presence of steep slopes on incompetent shale probably has resulted in a very unstable landscape that likely will present some engineering problems where the proposed route crosses it. Landsliding on a large scale has been documented in the region (Rutherford, 1930; Henderson, 1959; Hardy and others, 1962; and Thomson and Hayley, 1975).

River Crossing Characteristics

Two main considerations are involved in evaluating geologic characteristics of river crossings along the proposed route. One is the slope stability of terrain marginal to a river at a crossing, and the other involves actual dynamic changes of the river bed, terraces, banks, and stream hydrology. The former aspect is discussed in the preceding section, the latter is treated here.

A wide variety of dynamic changes can occur at a particular river crossing on an occasional, a seasonal, or even a yearly basis. These changes include bed aggradation or degradation, local scour, and lateral channel or bank migration.

The crossing of each stream and its floodplain is unique, and requires individual detailed study to predict future behavior from past history. Dynamic behavior is a function of such factors as (1) geologic materials exposed in valley walls, (2) local permafrost characteristics, (3) local climate, (4) texture of alluvium, and (5) slope and relief.

Two unusual features that occur in northern rivers should also be mentioned. Rivers flowing through permafrost terrain usually undergo a large reduction in flow during winter; some may actually cease to flow. A second phenomenon occurs along many of the rivers that flow northward, such as the Mackenzie River. In them, freezeup occurs first in lower stretches and breakup occurs first in upper reaches. This leads to ice dams and ice jams which can temporarily raise water levels. When an ice dam breaks, resulting high discharges may result in intense scour and rapid channel migration for short durations.

Other Geologic Hazards

Certain geologic conditions not described above occur along parts of the proposed route. Hazards include: (1) hidden sinkholes, (2) spontaneous combustion, and (3) rebound of shale bedrock.

The basal Middle Devonian rocks, the Bear Rock Formation, occur between Main Line Mileposts 293 and 396 and consist of dolomite, limestone, gypsum, and anhydrite. They are frequently brecciated and may be sink-forming and cavernous. Similar rocks are in the Campbell Lake area, Richards Island Supply Line Milepost 55.

Some sectors of a few of the geologic units in the areas crossed by the proposed route are subject to spontaneous combustion under certain conditions. One of these units is the Canol formation, of Middle Devonian age, which contains bituminous shale. The Formation occurs in the Fort Good Hope area (Figure 2.1.2.2-9), and in the Norman Wells area (Figure 2.1.2.2-10). Evidence of occurrences of natural, spontaneous combustion may be indicated by smoke, dead vegetation, products of the combustion process, or debris flows. Some of the petroliferous or bituminous shales of Upper Devonian age that occur along the proposed route also may show tendencies to combust spontaneously. Tertiary lignite beds in the Fort Norman area (Figure 2.1.2.2-11) also are subject to spontaneous combustion; some lignite beds have been afire for over a hundred years. Some of the Cretaceous carbonaceous shales exposed in river banks in the region of the crossings of the Peace River and Smoky River (Figure 2.1.2.2-20) of the proposed route also are known to be susceptible, locally, to spontaneous combustion. Combustion apparently occurs where landsliding of the shale has promoted oxidation of the minor iron sulfide constituent of the shale (Rutherford, 1930, p. 51).

Rebound is the slow upward movement of bedrock due to stress relief as the bedrock erodes. Results of the rebound process are evident in and near the deeply entrenched valleys being cut into the shales prevalent in the Great Plains of western Canada and central-northern United States. Movements may trigger some of the many landslides common along the margins of these valleys. Rebound has been measured in the bottoms of large, deep excavations in and near these valleys; movements of as much as 1 percent of excavation depth have been recorded (Matheson and Thomson, 1973). Although most measured rebound occurs soon after excavation, movement continued for at least 33 years at one location (Fleming et al., 1970), and presumably still is continuing.

Permafrost

General Description

Definition

Permafrost is defined as soil, rock, or any other earth material, the temperature of which remains at or below 32° F. (0° C) continuously for two or more years (Muller, 1947, p. 3). Thus, permafrost is defined exclusively on the basis of temperature, without regard to other conditions of the material, such as lithology, texture, degree of induration, or water (ice) content. The presence of ice is not a necessary prerequisite of permafrost; its presence, however, and the relative proportion of ice with respect to other material, is of extreme importance to the behavior of permafrost when it is degraded (thawed), and thus to the effect on structures sited on the permafrost (Pihlainen and Johnston, 1963).

The term "permafrost" is actually somewhat of a misnomer, because although "perma-" derives from the word permanent, a permafrost condition unfortunately is anything but permanent, and it is the nonpermanence of permafrost when its thermal environment is altered that gives rise to the problems this condition presents. "Perennially frozen ground" is a more accurate, if more cumbersome term, to describe this condition.

In addition to the references cited, much of the material in this section is derived from Ferrians, Kachadoorian, Cobb, and Page (1972, p. 6-10).

Distribution

Permafrost is widely distributed in all land areas at high latitudes and nearly half of the total land surface of Canada is underlain by permafrost. The distribution is not uniform and depends on many variables. Although mean annual air temperature is a basic factor in determining the distribution, mean annual ground temperature is the key item that determines the presence or absence of the phenomenon. There are several variables that relate these two values, including glacial and climatic history of an area;

thermal properties of the earth material; insulating properties and thermal balance of any overlying material such as vegetation, snow, or water bodies; topographic conditions such as orientation of a slope with respect to the sun; and other shade factors caused by topography or vegetation. To simplify the description of distribution, and to eliminate local and largely unknown variations, the permafrost region has been divided into two broad zones, the continuous zone and the discontinuous zone. The division between these two zones has been chosen, originally by Russian workers, as the line where the mean annual ground termperature is -5° C (23° F); this criterion has been widely adopted and is used in North America. The boundaries of these two zones, as well as other related information in western Canada, is shown on Figures 2.1.2.3-7 and -8, as they relate to the proposed route. These maps are based entirely on the map, "Permafrost in Canada," (Brown, 1967), as is much of the material in this section.

In the continuous zone, permafrost occurs everywhere beneath the ground surface except in newly deposited materials and beneath large bodies of water that do not freeze to the bottom in winter. In the discontinuous zone, there are areas of nonperennially frozen ground, as well as layers of ground within and above the frozen layers that do not freeze. This zone has a subzone, called in Canada the southern fringe (the sporadic zone of earlier terminology), in which permafrost occurrences are limited to isolated patches ranging in size from a few square feet to thousands of acres. This fringe zone itself has a few outliers, areas of permafrost beyond the zone generally considered to contain scattered occurrences of permafrost (Figure 2.1.2.3-8).

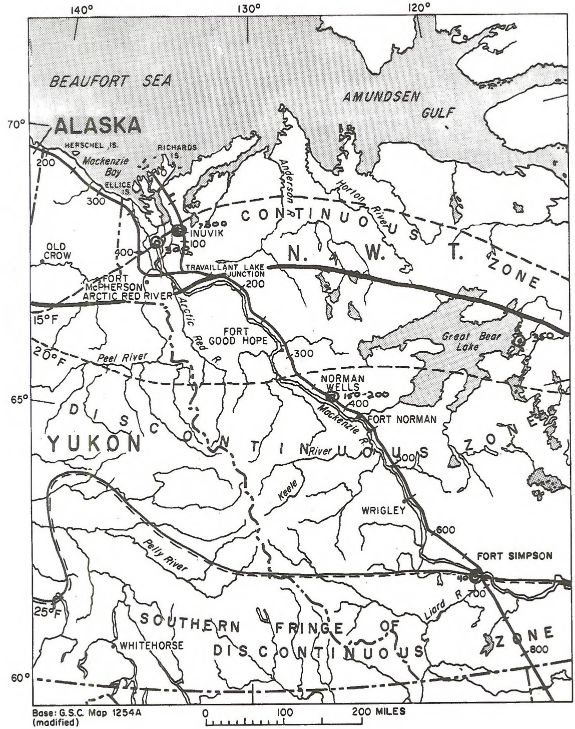
The distribution of permafrost (following patterns of mean annual air and ground temperature) also has a dependence on elevation of the ground which is difficult to portray on a small-scale map, and which is not known in detail. Both the map, "Permafrost in Canada" (Brown, 1967) and the "Permafrost Map of Alaska" (Ferrians, 1965) show this variation by references to physiographic settings. On the maps presented here, the high-elevation areas that may contain permafrost are generalized from Brown (1967). That report also contains a formula for approximating the elevation of the limit of permafrost for a given latitude in the Cordilleran Region.

Thickness

Permafrost varies in thickness from a few inches to well over 1,000 feet. Some known thicknesses in Canada (from Brown, 1967) are plotted on Figures 2.1.2.3-7 and -8. It should be noted that most of these sites are near large bodies of water, and thus may not provide values typical of thickness in the area in general. In the northern part of the continuous zone, thicknesses in excess of 1,000 feet can be expected; by analogy with a reported thickness of 2,000 feet near Prudhoe Bay in Alaska (Howitt and Clegg, 1970), similar thicknesses may be expected in parts of northern Canada traversed by the proposed route. At the boundary between the continuous and discontinuous zones, an average thickness of about 200 feet is expectable. Within the discontinuous zone, the thickness may be expected to decrease southward to a few inches at the margin; this decrease does not occur in any regular way but is dependent upon the many local variables mentioned with regard to distribution.

Depth to Permafrost

Permafrost does not usually extend to the ground surface, but is overlain by the suprapermafrost layer. This layer may consist entirely of a zone that freezes in winter and thaws in summer, known as the active layer,



Base: G.S.C. Map 1254A (modified)

Figure 2.1.2.3-7 Permafrost map north of 60° N latitude

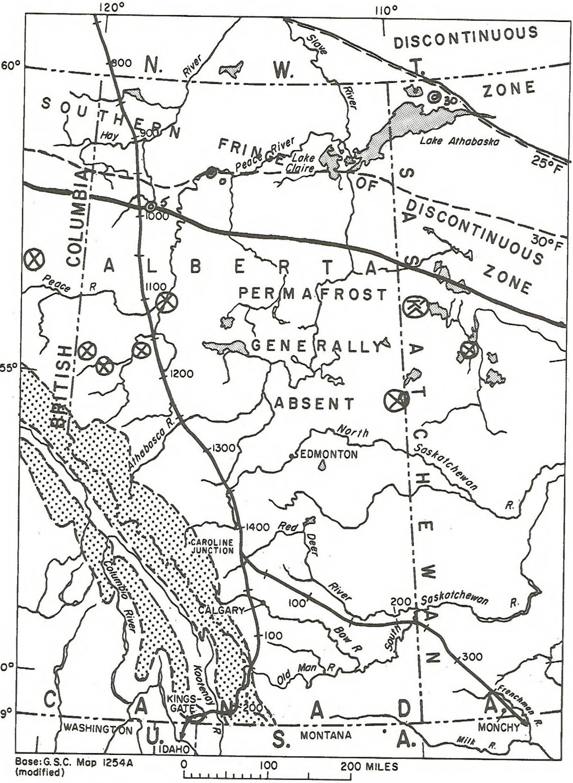


Figure 2.1.2.3-8 Permafrost map south of 60° N latitude

but may in addition include a layer beneath the active layer that does not freeze at all, known by the Russian term "talik." (The term "talik" also applies to unfrozen ground within or beneath permafrost, or where there is no permafrost.) In the continuous zone, the active layer is generally 1.5 to 3 feet thick, and there is no talik. In the discontinuous zone, the suprapermafrost layer is quite variable in thickness, ranging from a few feet in the northern part to several tens of feet generally farther south; particularly in the southern fringe there is likely to be talik many feet to tens of feet thick.

Temperature

Ground temperature (whether above or below the freezing point of water) varies both in depth and in areal distribution. The vertical variation in temperature is primarily a function of balance between heat from the center of the earth and mean annual air temperature. Where this balance is negative (with respect to the freezing point of water, 32° F), permafrost forms. Over a long period of time, if the balance continues to be negative, the depth of the bottom of the permafrost zone increases, until at some depth a quasi-equilibrium is reached, with a balance temperature of 32° F; this point marks the base of permafrost until some variable changes. In the upper part of the permafrost body, there is an annual fluctuation in temperature, where the fluctuation of air temperature is more influential than the steady flow of heat from below. The depth where the annual fluctuation is nil is usually taken as the nominal temperature of the permafrost. In the continuous zone in Canada, this temperature is about 5° F in the northernmost part, increasing irregularly to 23° F at the southern boundary, which is defined by this temperature. In the discontinuous zone, the nominal temperature increases to just below 32° F at the southern limit. The factors that control variations in the distribution of permafrost also affect the temperature, which varies markedly with depth, latitude, and geologic and topographic conditions. Large bodies of water (rivers, lakes, and oceans) are heat reservoirs that tend to increase the temperature of permafrost in adjacent areas, and that may cause permafrost to be absent beneath them. In mountainous areas the temperature is likely to be extremely variable.

Ice Content

The amount of ice present in the surficial deposits or bedrock in which the permafrost is developed can vary from none to nearly 100 percent. This proportion depends initially on the water present in the material before freezing, but during the process of formation of the permafrost (and during the freeze-thaw cycles in the suprapermafrost zone) the ice becomes segregated, particularly when the percentage is relatively high. This segregated ice may take the form of irregular blobs or lenses, more or less horizontal layers that may range in thickness from less than 1 inch to many feet, or vertically oriented wedges which thin downward and which may be tens of feet deep and several feet wide at the top in northern continuous zone (to the south they have smaller dimensions). These wedges occur in cracks formed in the ground when it contracts as it freezes; these cracks develop over long periods of time, and occur frequently in a polygonal pattern resembling mud cracks, but generally much larger. Ice-wedge systems are sometimes visible on the surface of the ground (ice-wedge polygons), but in many places there are ice wedges not revealed by a surface indication.

A system of describing ice content in permafrost has been developed (Pihlainen and Johnston, 1963), and is described briefly here. There are three basic divisions: (a) ice not visible to the eye (symbol N), (b) ice visible to the eye with individual ice layers less than 1 inch thick (symbol V), and (c) ice visible to the eye with individual ice layers greater than 1 inch thick (symbol ICE). These categories are further broken down as follows:

Nf	Ice bonds the material into a loose or friable mass.
Nbn	Material well bonded by ice, but there is no excess ice.
Nbe	Material well bonded by ice, but there is excess ice (supernatant water appears upon melting).
Vx	Individual ice crystals or inclusions.
Vc	Ice coatings on particles.
Vr	Random or irregularly oriented ice crystals.
Vs	Stratified or distinctly oriented ice formations.
ICE+	Ice masses with significant amounts of soil or other material (the material is named following the +).
ICE	Ice with only minor amounts of other material.

Modifications of Permafrost

As indicated above, it is the changes, chiefly degradation (thawing), that engineering works can bring about in permafrost that cause the "permafrost problem." This can happen in two basically different ways: (1) Changes in the thermal balance at the ground surface can cause the active layer to thicken from summer heating. Damage to the organic surface layer (especially its removal), gravel pads, or disruption of surface drainage can have a critical effect on roadways, pile foundations, and other structures. (2) Heated buildings, or other new and steady sources of heat, can change the equilibrium thawing configuration of the permafrost. Such a change may drastically affect the behavior of the material underlying the surface, but the change may not reach completion for decades, or even centuries (Lachenbruch, 1970). Thus, there is a very real possibility that problems may continue over a period of time which extends far beyond the life of the structure that initiated them.

The primary engineering problems resulting from thawing of permafrost relate to its potential loss of strength and volume (Ferrians, Kachadoorian, and Greene, 1969). In ice-rich material, this can cause severe differential settlement or loss of bearing strength in foundations. Such effects are often irreversible, and under adverse conditions may be self-perpetuating and difficult to predict. Where the permafrost is not ice rich, however, and the ice occurs in voids between grains of the soil or other material so that the grains are in firm contact, thawing of the permafrost does not induce the severe problems otherwise encountered.

Description Along the Proposed Route

An attempt is made here to summarize some permafrost conditions along the proposed route. Likelihood of presence of permafrost, and ice content of the material in which the permafrost is developed, are the principal conditions considered here. This discussion is based almost entirely on information in the Alignment Sheets (CAGPL, 1974f,g; 1975a, section 8.a.3). Most of this information is derived from airphoto interpretation, and it must be emphasized that the estimates of the likelihood of any occurrences given here are only approximations based on general knowledge gained elsewhere, rather than on hard data locally obtained. The ice-content values are based on field data, but these data are from widespread borings, many of them some distance removed from the proposed location of the route; ice-content values are likely to change considerably over short distances. Nevertheless the ranges of ice-content values cited are sufficiently broad as to give approximately correct orders of magnitude. Temperature, thickness, and other descriptive elements can only be estimated on the basis of the general descriptions given in the preceding section.

For the purpose of this discussion, four categories of permafrost conditions are established, as follows:

Category Z	Permafrost present throughout. Relatively high ice content, 20 to over 100 percent; 30 to 60 percent most common, higher values more likely in the continuous zone, lower values in the discontinuous zone
Category Y	Permafrost present everywhere in continuous zone, nearly everywhere in the discontinuous zone. Moderate ice content, generally 10 to 40 percent, 20 to 30 percent most common
Category X	Permafrost present nearly everywhere in the continuous zone; may be absent in the discontinuous zone, but in the southern fringe includes the areas most likely to have any permafrost. Relatively low ice content, generally less than 20 percent.
Category W	Permafrost generally absent.

North of 60° N Latitude

Permafrost is present nearly everywhere along the route of the proposed pipeline north of 60° N latitude. The routes of the Prudhoe Bay Supply Line and the Richards Island Supply Line lie entirely within the continuous zone of permafrost. The Main line leaves the continuous zone shortly beyond its beginning and thereafter traverses the discontinuous zone; the last 170 miles in Northwest Territories lie in the southern fringe of the discontinuous zone, where there are extensive route segments lacking permafrost (Figure 2.1.2.3-7).

Prudhoe Bay Supply Line--All of this part of the proposed route lies in the continuous zone of permafrost. Of the 297 miles of this proposed route, 262 miles (88 percent) is estimated to be in Category Z, 27 miles (9 percent) in Category Y, and 8 miles (3 percent) in Category X. Mileage in Category Z dominates the proposed route between Mileposts 195 and 465; the Category Y mileage is mostly between Mileposts 465 and 492 with small segments scattered between Mileposts 338 and 465; most of the Category X mileage is scattered between Mileposts 200 and 224. Ice contents are likely to be in the higher parts of the range in each category. The temperature of the permafrost is likely to be cold, 5° to 10° F. The thickness is likely to be several hundred to well over 1,000 feet, probably as much as 2,000 feet. The active layer is indicated on the Alignment Sheets as being only 1-2 feet thick in most places.

Richards Island Supply Line--This part of the proposed route is also all in the continuous zone. Of the 158 miles of this proposed route (including the Parsons Lake Lateral Line), 98 miles (62 percent) is estimated to be in Category Z, 35 miles (22 percent) in Category Y, and 25 miles (16 percent) in Category X. Most of the Category Z mileage lies in the first 10 miles, between Mileposts 19 and 25, and between Mileposts 47 and 129. Most of the Category Y mileage is between Mileposts 25 and 31 between Mileposts 129 and 143 at the end, and on the Parsons Lake Lateral Line. The Category X mileage is mostly between Mileposts 10 and 19 and between Mileposts 31 and 47. Ice contents are likely to be in the higher parts of the range in each category. Other elements are similar to those for the proposed Prudhoe Bay Supply Line, but near the Mackenzie River and some of the large lakes temperatures may be higher and thickness less.

Main Line--The proposed Main Line is in the discontinuous zone for most of the way between Travaillant Lake Junction and the N.W.T.-Alberta border, passing into the southern fringe at about Milepost 685. Of the 695 miles in this part of the proposed Main Line, 165 miles (24 percent) is estimated to be in Category Z, 203 miles (29 percent) in Category Y, 277 miles (40 percent) in Category X, and 50 miles (7 percent) in Category W. Most of the Category Z mileage occurs principally in 7 segments ranging from 2 to 94 miles in length between Mileposts 150 and 582, all in the discontinuous permafrost zone proper. Category Y mileage occurs in 11 segments that range in length from 3 to 57 miles, extending from the beginning of the line as far south as Milepost 658. All of the Category Y mileage, like that of Category Z, is limited to the regular part of the discontinuous zone.

Category X mileage extends throughout this part of the proposed route, from near the beginning to the end; it should be noted however that although the characteristics of this category remain about the same, there is a change in the significance of these characteristics: in the discontinuous zone, mileage in this category is that most likely to have some segments that do not contain permafrost; in the southern fringe, which begins at about Milepost 685, mileage in this category is that most likely to have permafrost, the remainder unlikely to have any. There are 13 principal segments that are included in Category X, ranging in length from 4 to 54 miles.

Category W mileages begin north of the boundary of the southern fringe at Milepost 599, extending into the southern fringe to Milepost 796; five segments have been identified, ranging in length from 1 to 28 miles.

Since this part of the proposed route spans the discontinuous zone and part of the southern fringe, the various descriptive elements will have values throughout the ranges cited in the general description. They will not be repeated here, because no more specific values are at hand.

South of 60° N Latitude

Only the northern part of the Main Line, and the parts of the Kingsgate Delivery Line at highest elevations traverse areas that are likely to have any permafrost, and these areas are generally restricted and sporadic in occurrence. They are not likely to have very high ice contents, but are likely to have temperatures just below the freezing point, and thus are readily susceptible to thawing. Most of the Main Line, most of the

Kingsgate Delivery Line, and all of the Monchy Delivery Line are in areas that are free of permafrost.

Main Line--The Main Line enters Alberta near Milepost 821 in a segment that continues to Milepost 874 and is placed in Category X. Other stretches of Category X extend from Mileposts 896 to 903, and 933 to 945. There appears to be a small patch about a mile long near Milepost 957. At Milepost 990 the proposed route passes from the southern fringe of the discontinuous zone into the area generally free of permafrost. At Milepost 1028 there is a suggestion that a small patch might be placed in Category X. Between Mileposts 1150 and 1170 the proposed route may pass near an area that contains permafrost (Figure 2.1.2.3-8). It is not clear from the Alignment Sheets that the route actually would pass through permafrost areas here, but this possibility cannot be discounted. Isolated occurrences could be encountered as far south as about Milepost 1200 but not much beyond that. Category W is applied to the parts of the proposed route not included in Category X above. In general, 74 miles (12 percent) of this route are included in Category X and 536 miles (88 percent) in Category W.

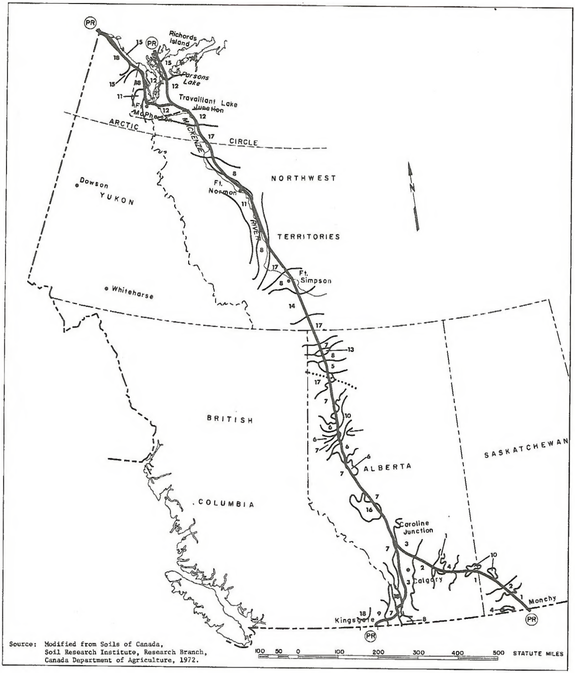
Kingsgate Delivery Line--This part of the proposed route is generally in country that is free of permafrost, but as it crosses the mountains, it reaches elevations where climatic conditions are such that the generation of permafrost is possible, and in some shaded places such as north-facing slopes, quite likely. The segments of the proposed route so situated are between Mileposts 137 and 140 crossing the Livingstone Range; a short stretch near Milepost 156; Mileposts 165 to 167 near Crowsnest Pass; a short stretch crossing into Flathead drainage near Milepost 196; the crossing of Flathead Ridge between Mileposts 198 and 207; and between Milepost 250 and 251 crossing Yahk Ridge. Thus about 6 percent of the route crosses ground that might contain permafrost, and is therefore placed in Category X; however, it is likely that only a smaller percentage actually does have any permafrost.

2.1.2.4 Soils

The term "soils" as used in this section applies to their agricultural use. Soils in the engineering sense are discussed in section 2.1.2.3 "Surficial Deposits." Therein are described the engineering characteristics of non-lithified materials, such as sand, gravel, silt, clay, and diamicton (mostly glacial till) that overlie the bedrock.

The soils are classified according to the Canadian soil classification system. Equivalent categories in Soil Taxonomy, used in the United States, are shown on figure 2.1.2.4-1.

The distribution of soils discussed here is shown by 18 map units on Figure 2.1.2.4-1. These map units are derived from the map, Soils of Canada, 1:5,000,000 scale, published by the Soil Research Institute, Research Branch, Canada Department of Agriculture, Ottawa, 1972. Because of the small scale of the Soil Research Institute map, the variation in kinds of information about soils available, the wide range in time over which reference materials were published, and the fact that soils differ greatly within short distances, precise descriptions of all soils that occur within the area represented by each map unit are not feasible. Rather, the dominant soil occupying the landscape of each map unit is characterized along with the more extensive associated soils. Such characteristics are summarized in Table 2.1.2.4-1 and discussed below. Much information was gleaned from the following references: Bowser et al., 1962; Bowser and



Source: Modified from Soils of Canada, Soil Research Institute, Research Branch, Canada Department of Agriculture, 1972.

Figure 2.1.2.4-1 Soils of Canada crossed by the proposed route

Legend

MAP UNIT	DESCRIPTION	
	Canadian Soil Classification	U.S. Soil Taxonomy Equivalent
	Chernozemic Soils	
1	Brown	Aridic Haploborolls and Aridic Argiborolls
2	Dark Brown	Typic Haploborolls and Typic Argiborolls
3	Black	Udic Haploborolls and Udic Argiborolls
	Solonetzic Soils	
4	Brown	Aridic Natriborolls and Typic Natriborolls
5	Black	Udic Natriborolls and Typic Natriborolls
6	Solod	Glossic Natriborolls and Natralbolls
	Luvisolic Soils	
7	Gray Luvisols	Typic Cryoboralfs
	Brunisolic Soils	
8	Eutric Brunisols	Typic Eutrochrepts and Eutic Cryochrepts
9	Dystric Brunisols	Typic Dystrochrepts
	Regosolic Soils	
10	Orthic Regosols	Udipsamments and Cryorthents
11	Cumulic Regosols	Cryofluvents
12	Cryic Regosols	Pergelic Cryorthents
	Gleysolic Soils	
13	Humic Gleysols	Cryaquolls
14	Gleysols	Typic Cryaquepts
15	Cryic Gleysols	Pergelic Cryaquepts
	Organic Soils	
16	Fibrisols and Mesisols	Cryofibrists and Cryohemists
17	Cryic Fibrisols	Pergelic Cryofibrists
	Rockland	
18	Rockland	Areas devoid of soil, Lithic Cryorthents and Pergelic Cryorthents

Special Symbols

----- southern limit of continuous permafrost

••••• southern limit of discontinuous permafrost

(PR) **Proposed Route**

Table 2.1.2.4-1 Estimated properties of soils along the proposed route

Map Unit	Soils	Thickness of Surface Layer (inches)	Dominant Texture			Depth to Bedrock (feet)	Reaction	Permeability	Other Soil Features
			Surface	Subsufrace	Substratum				
1	Chernozemic Brown	5-8	Loam, clay loam	Clay loam	Silty clay loam	> 10	Slightly acid to neutral	Moderately slow	35-60% of clay fraction is montmorillontic
2	Dark Brown	8	Loam, clay loam	Clay loam	Silty clay loam	> 10	Slightly acid to neutral	Moderate to moderately slow	35-60% of clay fraction is montmorillonitic
3	Black	6-15	Loam	Clay loam, silty clay loam	Silty clay loam	> 10	Neutral to mildly alkaline	Moderately slow to moderate	35-60% of clay fraction is montmorillonitic
4	Solonetzic Brown	6	Loam	Silty clay loam	Silty clay loam	> 10	medium acid to neutral	Slow	Saline soils, relatively high sodium content
5	Black	3-4	Loam	Silty clay loam	Silty clay loam	> 10	Medium acid to neutral	Slow	Saline soils, relatively high sodium content
6	Solod	10	Silt loam	Clay loam, clay	Silty clay, clay	> 10	Medium to slightly acid	Slow	Saline soils, relatively high sodium content
7	Luvisolic Gray Luvisols	6	Loam	Clay, clay loam	Silty clay, clay	> 10	Strongly acid to mildly alkaline	Moderately slow to moderate	

Table 2.1.2.4-1 (Continued)

Map Unit	Soils	Thickness of Surface Layer (inches)	Dominant Texture: Surface	Dominant Texture: Subsurface	Dominant Texture: Substratum	Depth to Bedrock (feet)	Reaction	Permeability	Other Soil Features
	Brunisolic								
8	Eutric Brunisols	6	Clay loam	Silty clay	Silty clay	< 10	Mildly alkaline	Moderate	
9	Dystric Brunisols	2-4	Loam	Clay loam	- -	< 5	Extremely to strongly acid	Moderate	
	Regosolic								
10	Orthic Regosols	3-6	Loamy sand	loamy sand, sand	Sand	> 10	Strongly to slightly acid	Rapid	
11	Cumulic Regosols	4-6	Clay loam	Clay loam	Silty clay loam	> 10	Medium acid	Moderate	
12	Cryic Regosols	4	Clay loam	Clay loam	- -	< 5	Extremely to medium acid	Moderate	Permafrost a few inches beneath the surface
	Gleysolic								
13	Humic Gleysols	4	Clay loam	Clay	Clay	> 10	Medium acid to neutral	Moderately slow to slow	Saline substratum
14	Gleysols	2-4	Gravelly loam	Loam	Silty clay	> 10	Strongly acid to neutral	Moderately slow to slow	
15	Cryic Gleysols	2-4	Gravelly loam	Loam	Silty clay	< 5	Medium acid	Moderately slow	Permafrost a few inches beneath the surface
	Organic								
16	Fibrisols & Mesisols	> 60	Peat	- -	- -	> 5	Extremely to medium acid	- -	
17	Cryic Fibrisols	> 60	Peat	- -	- -	> 5	Extremely to medium acid	- -	Permafrost near surface
18	Rockland	-	- -	- -	- -	< 2	- -	- -	

Peters, 1951; Day, 1966, 1968; Day and Rice, 1964; Dumanski et al., 1972; Kelley and Sprout (no date); Lindsay et al., 1963; Mitchell et al., 1947; Moss, 1965; Moss and Clayton, 1967; Odynsky and Newton, 1950; Odynsky et al., 1952, 1956; Peters and Bowser, 1959; Pettapiece, 1975; Reeder and Odynsky, 1969; Scheelar and Macyk, 1972; Scheelar and Odynsky, 1968; Tarnocai, 1973; Twardy and Lindsay, 1971; University of Alberta, 1945; Wyatt, 1935, 1939; Wyatt and Newton, 1927, 1942, 1943; Wyatt, Newton and Mather, 1930; Wyatt and Younge, 1930; Zoltai and Pettapiece, 1973; Zoltai and Tarnocai, 1974.

Soils Along the Proposed Route

Chernozemic Soils

Brown Chernozemic Soils

Brown Chernozemic soils (Map Unit No. 1) are dominant along the Monchy Delivery Line between Mileposts 124 and 215 near the Alberta-Saskatchewan border. They are mostly well drained soils developed in glacial till having a high proportion of silt and clay. Slopes are gentle to moderate; a small proportion of the landscape is hummocky.

Typically these soils have brown or grayish brown loam or clay loam surface layers 5 to 8 inches thick. The subsurface layer is approximately 15 to 24 inches thick, is brown or yellowish brown in color, and has blocky or prismatic structure. A layer of calcium carbonate accumulation usually occurs 15 to 20 inches beneath the surface of the soil. The substratum is calcareous glacial till.

Brown Chernozemic soils are highly productive for adapted crops. They are well supplied with plant nutrients. The soils are moderately to slowly permeable. These soils are subject to periods of drought.

Dark Brown Chernozemic Soils

Dark Brown Chernozemic soils (Map Unit No. 2) are on the gently sloping plains between Mileposts 67 and 124 on the Monchy Delivery Line. They have many features in common with the Brown Chernozemic soils. The differences between them are due mainly to the slightly higher precipitation in the region of the Dark Brown Chernozemic soils.

Typically, these soils have a dark brown surface layer about 8 inches thick. Dominant textures are loams. Subsurface layers are somewhat finer in texture than the surface layers and have weak prismatic structure. The layer of accumulation of calcium carbonate is commonly at depths of 20 to 24 inches.

Along most of the Monchy Delivery Line, the Dark Brown Chernozemic soils have developed in glacial till; however, between Mileposts 85 and 98, they have developed in deposits of lacustrine origin and surface textures are clay loams and clays. Immediately south of the Monchy Delivery Line between Mileposts 67 and 85, where glacial deposits have been subjected to transport and sorting by water, soil textures are sandy loams and fine sandy loams.

Like the Brown Chernozemic soils, the Dark Brown Chernozemic soils are highly productive. Although soil moisture is somewhat limiting for crops, periods of drought are of shorter duration and occur less frequently than in the region of Brown Chernozemic soils.

Black Chernozemic Soils

Black Chernozemic soils (Map Unit No. 3) are on the gently and moderately sloping plains between Mileposts 15 and 40 on the Monchy Delivery Line, and between Mileposts 30 and 95 on the Kingsgate Delivery Line. The soils are well and moderately well drained soils developed in deep glacial till having a high proportion of silt and clay.

Typically these soils have black or nearly black cloddy or granular loam surface layers 6 to 15 inches thick. The subsurface layer has a somewhat greater proportion of clay than the surface layer, has blocky structure, and is firm or hard. A layer of calcium carbonate is approximately 24 inches beneath the surface of the soil.

The Black Chernozemic soils are the most productive soils in Canada. They are well supplied with plant nutrients and have adequate supplies of moisture available for crops. A high percentage of the area of these soils is used for production of grains.

Solonetzic Soils

Brown Solonetz

Brown Solonetz (Map Unit No. 4) are on the gently sloping plains between Mileposts 135 and 170 on the Monchy Delivery Line. They are well to moderately well drained soils developed in parent materials having moderate to high contents of sodium and magnesium salts.

Brown Solonetz have a somewhat cloddy loamy surface layer approximately 6 inches thick. The subsurface layer is brown or grayish brown in color, has a layer of clay accumulation with a relatively high content of sodium, and is hard when dry.

These soils have a relatively low potential for crop production. The hard subsurface layer precludes penetration by plant roots and the surface layer is difficult to maintain in a good state of tilth.

Black Solonetz

Black Solonetz (Map Unit No. 5) are in the cooler subhumid region west of Fort Vermilion, generally between Main Line Mileposts 920 and 960. They are on gently to moderately sloping glacial till plains.

These soils are similar to the Brown Solonetz but have a black organic-rich granular surface 3 or 4 inches thick overlying the clayey subsurface layer.

Among the Black Solonetz are organic soils on level and depressional areas.

Solod

Solods (Map Unit No. 6) are on level to very gently sloping surfaces adjacent to the Peace River, generally between Main Line Mileposts 1083 and 1230. They are drained and moderately well drained soils developed on mixed saline lacustrine deposits and glacial till.

Typically, these soils have a brown, friable silt loam surface layer approximately 10 inches thick. The subsurface layer is also brown in color, but consists of a blocky clay loam overlying very firm clay having prismatic structure. The substratum with calcium carbonate and soluble salts is approximately 24 inches beneath the surface of the soil.

The Solods have some potential for production of crops. They are medium acid to neutral in reaction and respond well to applications of lime and fertilizer. Much of the area in which these soils occur either is virgin land, idle, or in pasture; some of it which was once under cultivation is now abandoned. Production of cultivated crops would be severely limited by the cold climate and the short growing season.

On level and depressional areas other Solods, moderately well to poorly drained, have developed in calcareous and saline lacustrine clays. These soils have friable clay loam surfaces 6 to 10 inches thick over firm blocky clay subsoils. Depth to the calcareous and saline substratum is about 36 inches. Like the better drained Solods, these soils respond to fertilization and have potential for producing moderate yields of crops but the fine texture makes them difficult to manage and the growing season is short.

Luvisolic Soils

Gray Luvisols

Gray Luvisols (Map Unit No. 7) are extensively distributed across the plains of central and western Alberta, mostly between Mileposts 982 and 1430 on the Main Line. They are well drained and moderately well drained soils developed on neutral or alkaline glacial till.

The dominant soils have dark grayish brown fine sandy loam or silt loam surfaces about 6 inches thick. The subsoil is dark yellowish brown, very firm, blocky clay. The glacial till substratum is approximately 30 inches beneath the surface.

These soils have relatively low potential for crop production. The fine-textured blocky subsoil is slowly permeable and resists penetration by roots. The soils are not well-supplied with plant nutrients. However, they respond to good management, including the use of lime and fertilizer. Use of these soils for cropland is also limited by the short growing season.

Associated with the Luvisols and generally occurring on level and depressional areas are soils having organic surface layers. Where the organic surface contains more than 30 percent organic matter, the associated soils are Organic soils; where the content of organic matter is less than 30 percent, the soils are Gleysols. The organic surface consists of layers of peat differing from one another in color and composition. Total thickness of the organic layer generally does not exceed 48 inches. The ground-water table in these soils is at or within a few inches of the surface throughout the year. In the northern range of this soil permafrost occurs sporadically in the substrata of these wet soils.

Brunisolic Soils

Eutric Brunisols

Eutric Brunisols (Map Unit No. 8) are the dominant soils on the steep slopes of the Franklin Mountains east of the Mackenzie River in the

Northwest Territories. They are well drained soils developed in neutral to alkaline glacial till.

These soils have a dark grayish brown clay loam surface layer approximately 6 inches thick, commonly with a 3 or 4 inch cover of organic material. The subsurface layer is pale brown blocky silty clay which is slightly hard when dry. The substratum of glacial till is approximately 25 inches beneath the surface.

Depth of soil over bedrock varies from place to place. In many places the glacial till substratum is as much as 10 to 15 feet thick, but on hill crests, ridges and steep slopes, the soils are only a few feet thick and exposures of bedrock are common.

Among these Eutric Brunisols are poorly drained Gleysols. These wet soils are on nearly level to strongly sloping areas. They have a peaty surface 10 to 12 inches thick over a somewhat blocky heavy loam to silty clay subsurface layer. Commonly, these soils are frozen (permafrost) at depths of 20 to 24 inches beneath the surface of the covering peaty layer.

The Eutric Brunisols support a mixed broadleafed and coniferous forest. In the more northern parts of the area dominated by these soils, and at the higher elevations, coniferous forest, mainly black spruce, is dominant.

Dystric Brunisols

Dystric Brunisols (Map Unit No. 9) are the dominant soils at the southern end of the Kingsgate Delivery Line between Milepost 136 and the U.S.-Canada border. Except in the Kootenay and Elk River valleys, where the parent materials are calcareous glacial till, the Dystric Brunisols have developed in weathered residuum of the sedimentary rocks of the southernmost part of the Rocky Mountains.

In this part of Canada, these soils are thin. They have silt loam or loam surfaces a few inches thick; the subsoil is somewhat finer textured. Bedrock is less than 3 feet beneath the surface of the soil.

These are forested soils limited for more intensive use by the steep slopes on which they have formed.

In the valley of the Kootenay and Elk Rivers, the soils are deeper and the upper part of the substratum comprises deep glacial till. The soils in the valley are grayish brown silt loams about 4 inches thick over pale brown granular to slightly blocky silt loam subsurface layers. The substratum of glacial till or glacial outwash is at a depth of approximately 36 inches.

The Brunisolic soils in these locations are mostly in forest. However, where slopes are gentle, the soils have potential for producing moderate yields of cultivated crops. Supplemental irrigation would be required, along with good management, for maximum yields.

Regosolic Soils

Orthic Regosols

Along the Monchy Delivery Line, Orthic Regosols (Map Unit No. 10) comprise the soil cover of the Great Sand Hills and the Middle Sand Hills in the vicinity of the South Saskatchewan River.

These soils are structureless sands in both active and stabilized dunes. There is little difference between surface and subsurface soil except for a thin surface layer slightly darkened by organic matter. Some thin darkened bands of former surface layers are irregularly spaced beneath the surface. Soil textures are mostly fine sand.

These sandy Regosols are subject to wind erosion. They are very low in plant nutrients and are very droughty. As a consequence, the potential of these soils for crop production is very low, although they have some potential for carefully managed grazing where forage grasses are established.

Orthic Regosols also comprise the soils of the Peace River valley and the adjacent steeply sloping dissected valley walls. Those on the valley floor consist of layers of sand, silt, and clay; those on the valley walls are similar and overlie massive glacial till.

These Regosols have little potential for use other than as pasture, wildlife areas, and forest. The valley floor is subject to periodic flooding and the side slopes are too steep for development.

Cumulic Regosols

Cumulic Regosols (Map Unit No. 11) are extensive on the gently rolling plain bordering the Mackenzie River in the northwestern part of the Northwest Territories. The soils have hummocky surfaces.

A surface blanket of organic material varying in thickness from 3 or 4 inches to as much as 15 or 18 inches covers an organic-rich clay loam or silty clay loam layer usually less than 6 inches thick. The brown subsurface layer is granular to somewhat blocky and of similar texture. The substratum of glacial till is permanently frozen, commonly at depths of 18 inches to 2 feet from the surface.

These are predominantly forested soils. Limitations imposed by the severe climate of the area in which they occur generally preclude use of these soils for any purpose other than for forest and wildlife areas.

Associated with the Cumulic Regosols are poorly and very poorly drained sites with Gleysols and Organic soils.

The Gleysols have a peaty layer approximately 8 inches thick blanketing the surface. The soil beneath the peaty layer is a blocky gray silty clay. Commonly, these soils are frozen below depths of 15 inches. The Organic soils are similar but have a much thicker surface layer of organic matter in various stages of decomposition.

Cryic Regosols

Cryic Regosols (Map Unit No. 12) are north of 67° N latitude. They are broadly distributed across the plains of the northern part of the Northwest Territories, including the delta of the Mackenzie River. Along the route of the pipeline they are on alluvial materials and thin deposits of glacial till. Stony areas and exposures of bedrock are common and locally extensive.

These Regosols are similar to the Cumulic Regosols except that the subsoil is perennially frozen from a few inches below the peaty surface downward.

Because of the severe climate, and presence of permafrost close to the surface, these soils have potential only as wildlife areas and for grazing by animals adapted to the region.

Gleysolic Soils

Humic Gleysols

Humic Gleysols (Map Unit No. 13) are of very small extent, occurring in a single area of lacustrine clay deposits along the Peace River in the vicinity of Milepost 1108 on the Main Line. Slopes are level.

The soils have a surface layer of very dark gray granular clay loam about 4 inches thick. The subsurface layer is yellowish brown mottled clay 18 to 20 inches thick and has weak prismatic structure. The substratum of alkaline clay is slightly saline.

These soils are very slowly permeable. The level of the groundwater table fluctuates seasonally and the soils are inundated during the spring.

Presently these soils support a grass cover with scattered clumps of willow. Potential for other than producing salt tolerant grasses for grazing is low.

Gleysols

Gleysols (Map Unit No. 14) are poorly drained soils saturated with water much of the growing season. They are poorly drained soils on level to very gently sloping plains of glacial till in places overlain by lacustrine silt and clay and by deposits of sand, silt and gravel.

These soils have either a covering layer of organic material less than 12 inches thick, or an organic-rich gravelly loam surface not more than 4 inches thick. The subsoil in either case is brown mottled loam. The substratum is calcareous silty clay loam.

The Gleysols are slowly permeable soils. They are subject to seasonal flooding and in some places are stony. They have little potential for use as cropland or for pasture.

Cryic Gleysols

Cryic Gleysols (Map Unit No. 15) are poorly drained soils with permafrost within 40 inches of the surface of the soil and in many places immediately beneath the surface cover of organic material. They have physical characteristics and associated soils similar to those of the Gleysols described above.

Organic Soils

Fibrisols and Mesisols

Fibrisols and Mesisols (Map Unit No. 16) are organic soils in which the organic material has reached no more than the intermediate stage of decomposition. In the former, the origin of the organic material is readily identifiable and in the latter the organic matter is partly altered, both physically and chemically. They have developed in areas of seeps, hummocky ground and swamps; in some instances they have overgrown areas of open water.

Organic soils like those in northwestern Alberta are widely distributed among the Gleysols. Most have perennially frozen glacial till substrata.

Areas in which these soils are the dominant soils on the landscape along the pipeline are few; the soils occur most extensively along the Main Line in the vicinity of Mileposts 1290 to 1350. They are also significant subdominant parts of the landscape in association with Luvisolic soils. They occur on depressional and level to very gently sloping areas.

The Fibrisols and Mesisols have a surface layer of peat generally more than 5 feet thick over the underlying mineral soil. Where the Fibrisols and Mesisols are associated with Luvisols, the dominant substratum is glacial till. They are commonly saturated within a few inches of the surface.

These soils have a low potential for productive forest and virtually none for use as cropland. They have some potential for grazing and are suited for wildlife habitats.

Cryic Fibrisols

The Cryic Fibrisols (Map Unit No. 17) are dominant on the level and very gentle slopes of plains situated in the latitude of the Arctic Circle about 66° 30'N. They are also significant associates of other soils along the pipeline north of the Peace River.

These soils are similar in most features to the Fibrisols and Mesisols occurring to the south. The organic materials comprising them are only slightly decomposed. Cryic Fibrisols have a permanently frozen layer within 5 feet of the surface of the soil. Depth to the frozen layer varies with the origin of the organic material as well as the climate in the region. Areas of thin soils and areas completely devoid of soil cover of any kind are common.

Like the Fibrisols and Mesisols to the south, the Cryic Fibrisols have no potential for development. They have potential only for the limited grazing they afford and for wildlife habitat.

Miscellaneous Areas

Rockland (Map Unit No. 18) comprises bedrock exposures with the intervening areas covered by soil, in many places thin and commonly stony. Slopes are steep.

Other than the natural vegetation they support, areas of Rockland have no potential for development.

2.1.2.5 Water Resources

Surface Water

This discussion of water resources along the proposed route is based on an evaluation of information in documents submitted by the Applicant to United States and Canadian governmental agencies and basic-data reports by the Water Survey of Canada.

The references listed were used to provide the description of the general quality and quantity of surface and ground waters.

The principal drainage system crossed by the Canadian part of the proposed pipeline route is the Mackenzie River. The Mackenzie River and its tributaries drain about 700,000 square miles in northern Canada, making it the second largest river in North America, both in size of drainage area and magnitude of discharge. The Prudhoe Bay Supply Line crosses the drainage basins of several rivers that drain directly into the Arctic Ocean. In southern Canada the proposed route crosses the basins of the North and South Saskatchewan Rivers of the Nelson River system, Kootenay River of the Columbia River system, and Milk River tributaries of the Missouri River system (figures 2.1.2.5-1 and 2).

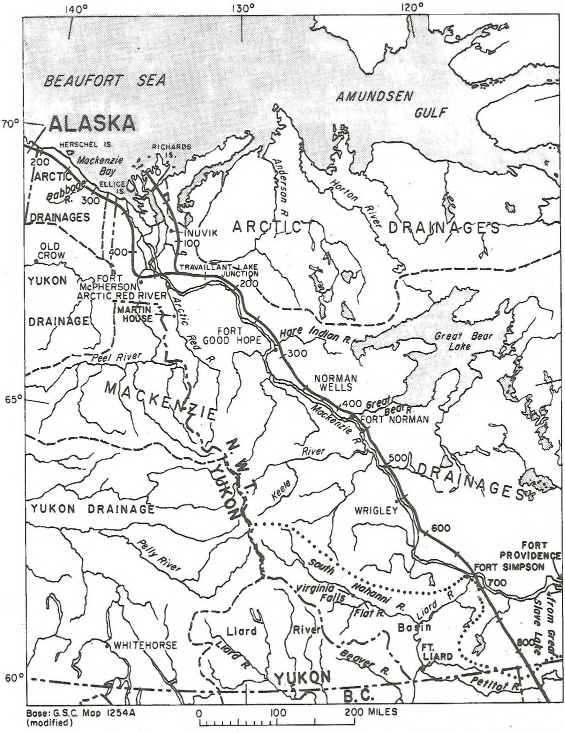
Data in Section 2.1.2.5 were taken from references which use both English and metric conversions in units of measurement. The original systems are retained herein because the conversion of units would change significant figures and increase the probability of error, particularly in tables.

Surface water in streams, lakes, and wetlands along the proposed route vary in distribution, availability, and quality. The average annual runoff is less than 1 inch in southeastern Alberta and southwestern Saskatchewan and more than 40 inches near the crest of the Rocky Mountains. During the winter many of the streams have no flow and many of the shallow lakes and wetlands are completely frozen. Some streams flow during the winter months because they are downstream of large lakes or connected to ground-water reservoirs. Floods can occur because of spring-breakup and ice jams, snowmelt runoff, summer storms (generally on the smaller streams), or a combination of conditions. Table 2.1.2.5-1 lists 46 streams which have drainage areas of at least 300 square miles above the point of the proposed pipeline crossings. Permafrost may affect summer streamflow by reducing infiltration, increasing flood runoff and reducing basal flow. Table 2.1.2.5-2 presents information about selected stream-gaging stations and streamflow statistics for the proposed route. Where data are scarce, every station is shown regardless of the length of record or distance from the proposed route. Where data are more sufficient, only information on the major rivers or smaller representative streams pertinent to the proposed pipeline route is given.

The magnitude of flow varies seasonally. Monthly variations in streamflow are shown in ratio to the mean annual flow for some of the larger rivers in Figure 2.1.2.5-3. Low runoff occurs in late winter when precipitation is stored as ice and snow. Maximum flow usually occurs as the result of snowmelt in May or June.

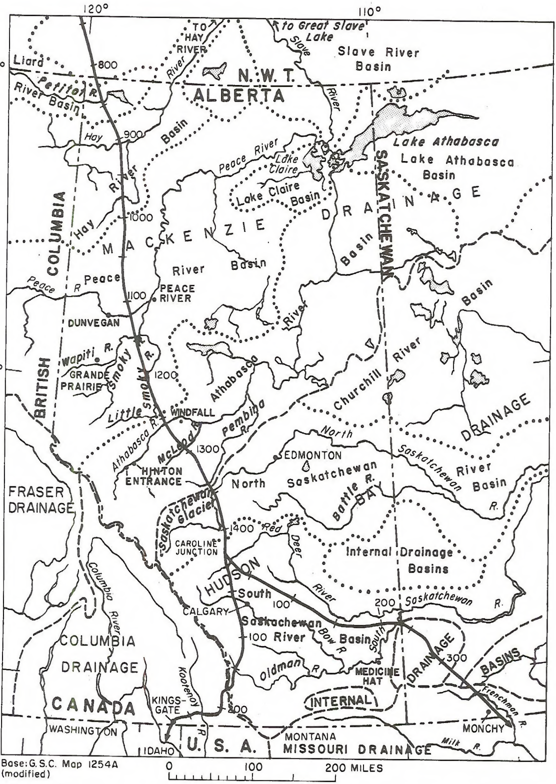
Glaciers occur on the eastern side of the Mackenzie and Rocky Mountains. No data are available on glaciers in the Richardson and British Mountains; no glaciers are located immediately along the proposed route. Glacier activity in the headwater areas, however, affects the flow and quality of glacier-fed rivers crossed by the proposed route. The degree of influence is controlled primarily by the size and activity of glaciers, the distance downstream from glaciers, and the size of the lakes in the water course.

In general, the rivers along the proposed route have water of good quality, soft to moderately hard. At the extreme southern end of the route some stream water contains large amounts of alkali sulfate; the water is of poor quality and may require treatment before use. The general water-quality characteristics of major stream systems are shown in Figures



Base: G.S.C. Map 1254A (modified)

Figure 2.1.2.5-1 Drainage basins and selected place names in the region of the proposed route north of 60° N latitude



Base: G.S.C. Map 1254A (modified)

Figure 2.1.2.5-2 Drainage basins and selected place names in the region of the proposed route south of 60° N latitude

Table 2.1.2.5-1 Major rivers crossed by the proposed route

NAME	MAP REFERENCE (fig. no. in this volume)	DRAINAGE AREA (mi^2)
Firth River	2.1.2.2-3	2,240
Malcolm River	2.1.2.2-3	380
Crow River	2.1.2.2-3	370
Babbage River	2.1.2.2-4	900
Blow River	2.1.2.2-4	950
Fish River	2.1.2.2-4	875
Rapid Creek	2.1.2.2-4	360
Rat River	2.1.2.2-5	935
Peel River	2.1.2.2-5	27,300
Mackenzie River	2.1.2.2-5	650,000 (approx.)
Travaillant River	2.1.2.2-8	900
Tieda River	2.1.2.2-9	340
Loon River	2.1.2.2-9	1,150
Hare Indian River	2.1.2.2-9	4,650
Donnelly River	2.1.2.2-9	460
Great Bear River	2.1.2.2-11	59,000
Big Smith Creek	2.1.2.2-11	330
Blackwater River	2.1.2.2-11	3,400
Ochre River	2.1.2.2-12	460
River Between Two Mountains	2.1.2.2-13	1,350
Willowlake River	2.1.2.2-13	8,330
Mackenzie River	2.1.2.2-14	500,000 (approx.)
Trout River	2.1.2.2-15	2,420
Kakisa River	2.1.2.2-15	5,770
Hay River	2.1.2.2-17	18,500
Chinchaga River	2.1.2.2-18	4,160
Notikewin River	2.1.2.2-19	1,810
Peace River	2.1.2.2-20	72,000
Smoky River	2.1.2.2-20	18,500
Little Smoky River	2.1.2.2-21	4,130
Athabasca River	2.1.2.2-21	6,990
McLeod River	2.1.2.2-22	2,480
Pembina River	2.1.2.2-22	1,710
North Saskatchewan River	2.1.2.2-22	4,220
Red Deer River	2.1.2.2-24	954

Table 2.1.2.5-1. (Cont.)

NAME	MAP REFERENCE (fig. no. in this volume)	DRAINAGE AREA (mi^2)
Little Red Deer River	2.1.2.2-24	924
Rosebud River	2.1.2.2-25	1,400
South Saskatchewan River	2.1.2.2-26	25,600
Swiftcurrent Creek	2.1.2.2-28	567
Frenchman River	2.1.2.2-28	(Regulated)
Bow River	2.1.2.2-29	2,500
Elbow River	2.1.2.2-29	306
Highwood River	2.1.2.2-30	300
Elk River	2.1.2.2-31	1,710
Kootenay River	2.1.2.2-31	5,200
Moyie River	2.1.2.2-31	570

Table 2.1.2.5-2 Summary of selected streamflow records along the proposed route 1/

Station 2/ no.	Name 4/	Map 3/ reference	Drainage area (sq.mi.)	Location	Years of Discharge records	Type 5/ of gage	Opera- 6/ tion	Mean 7/ (cfs) (in)	Max. 7/ daily (cfs)	Min. 7/ daily (cfs)	Remarks
	ARCTIC DRAINAGES:										
10MD001	Firth R nr Mouth, Y.T.	2.1.2.2-3	2,240	69°25' 139°30'	72-	R	C	-	18,200 6-27-72	0 12-72&73	
	MACKENZIE RIVER:										
10FB001	Mackenzie R nr Fort Providence, N.W.T.	8/	375,000	61°15'04" 117°29'48"	63-	R	C	150,000 5.43	312,000 7-9-64	36,000 4-16-69	Regulated since 1968
10FA002	Trout R at Fort Simpson Hwy, N.W.T.	8/	3,510	61°08'00" 119°49'30"	69-	R	C	a1,100 4.3	8,290 5-18-72	0 3- -72	
10BE001	Liard R at Lower Crossing, B.C.	8/	40,300	59°24'48" 126°05'35"	44 46-	M M	S C	40,500 12.02	301,000 6-13-64	4,400 3-21-66	
10BE005	Liard R ab Beaver River, B.C.	8/	45,800	59°44'33" 124°28'35"	68-	R	C	46,000 13.6	272,000 6-3-72	6,800 3-31-69	
10ED001	Liard R at Fort Liard, N.W.T.	8/	85,700	60°14'35" 123°28'45"	59-65 66-	M R	C C	68,600 10.87	b654,000 7-11-63	6,080 2-19-72	
10EB001	S Nahanni R ab Virginia Falls, N.W.T.	8/	5,650	61°38'00" 125°48'00"	60-63 64-	R R	S C	8,500 20.4	58,800 6-13-64	562 3-13-72	
10EC001	S Nahanni R ab Clausen C, N.W.T.	8/	12,900	61°15'10" 124°02'10"	59-62 63-	R R	S C	16,000 16.8	b290,000 6-17-62	1,310 2-11-73	
10ED002	Liard R nr mouth, N.W.T.	2.1.2.2-14	a95,000	61°34'40" 121°24'50"	72-	R	C	a88,000 12.6	530,000 6-21-73	13,500 3-8-73	
10GC001	Mackenzie R at Fort Simpson, N.W.T.	2.1.2.2-14	491,000	61°52'28" 121°20'08"	38-61 62-65 66-	M R R	S S C	224,000 6.20	830,000 5-30-61	53,800 3-23-69	Regulated since 1968

1/ Water Survey of Canada annual data reports
2/ - 8/ See notes at end of table

Table 2.1.2.5-2 (Continued)

Station[2/] no.	Name[4/]	Map[3/] reference	Drainage area (sq.mi.)	Location	Discharge records	Type[5/] of gage	opera-[6/] tion	Mean[7/] (cfs) (in)	Max.[7/] daily (cfs)	Min.[7/] daily (cfs)	Remarks
10GC003	Martin R nr mouth, N.W.T.	2.1.2.2-14	a600	61°53'10" 121°37'05"	72-	R	C	a180 4.0	2,420 6-28-73	4.4 12-17-73	
10GB001	Willowlake R nr mouth, N.W.T.	2.1.2.2-13	8,330	62°39'10" 122°54'50"	64-	R	C	2,080 3.39	34,400 5-14-67	50 3-8-66	
10HB001	Redstone R nr mouth, N.W.T.	2.1.2.2-11	6,080	64°11'00" 124°40'20"	64-	R	C	(c)	(c) 1970	(c)	
10HC003	Big Smith C nr Mackenzie Hwy, N.W.T.	2.1.2.2-11	a330	64°36'00" 124°48'00"	73-	R	C	-	-	-	Recently installed
10JC003	Great Bear R at O of Great Bear L, N.W.T.	8/	56,300	65°08'10" 123°30'30"	67 62-66,68-	R R	S C	20,100 4.85	d26,500 8- -61	e5,240 4- -48	
10KA001	Mackenzie R at Norman Wells, N.W.T.	2.1.2.2-10	606,000	65°16'54" 126°50'58"	43-56 62-	M R	S C	288,000 6.45	900,000 7-25-72	74,600 3-11-69	
10LA002	Arctic Red R nr Martin House, N.W.T.	8/	5,840	66°47'10" 133°06'00"	68 69-	R R	S C	a5,100 12	b193,000 7-22-70	300 3-2-72	
	MACKENZIE RIVER (PEEL CHANNEL):										
10MC002	Peel R ab Fort McPherson, Y.T.	8/	27,300	67°13'15" 134°56'45"	69-	R	C	(c)	176,000 6-4-71	1,620 4-15-72	
	HAY RIVER/MACKENZIE RIVER:										
07OA001	Sousa C nr High Level, Alta.	2.1.2.2-17	318	58°36' 118°36'	70-	R	S	a80 3.4	b1,220 5-13-70	No flow Many days	
07OC001	Chinchaga R nr High Level, Alta.	2.1.2.2-17	4,160	58°35'48" 118°20'00"	69-	R	C	1,360 4.42	b27,200 5-7-72	0.1 2-21-71	
07OB001	Hay R nr Hay River, N.W.T.	8/	18,500	60°44'45" 115°51'20"	29-31 63-	M R	S C	2,950 2.17	b36,000 5-10-64	10 2-11-71	

Table 2.1.2.5-2 (Continued)

Station[2/] no.	Name[4/]	Map[3/] Reference	Drainage area (sq.mi.)	Location	Discharge records	Type[5/] of gage	Opera-[6/] tion	Mean[7/] (cfs) (in)	Max.[7/] daily (cfs)	Min.[7/] daily (cfs)	Remarks
070C001	Kakisa R at O of Kakisa Lake, N.W.T.	8/	5,770	60°55' 117°25'	62 63-	M R	S C	1,340 3.15	b7,140 6-19-67	80 3-15-72	
	PEACE RIVER/ MACKENZIE RIVER:										
07FD003	Peace R at Dunvegan Bridge, Alta.	8/	50,200	55°55'13" 118°36'20"	60-69	M	S	f56,000	391,000 6-14-64	f19,020 8-30-61	Regulated since 1968
07GE001	Wapiti R nr Grande Prairie, Alta.	8/	4,350	55°04'20" 118°48'10"	17-18,51 60-71 72-	M M R	S C C	3,830 11.96	130,000 6-13-72	100 4-19-63	
07GH002	L Smoky R nr Guy, Alta.	2.1.2.2-20	4,130	55°27'25" 117°09'40"	59-62 63	M R	C C	1,760 5.79	36,900 4-29-65	23 2-13-62	
07GJ001	Smoky R at Watino, Alta.	2.1.2.2-20	18,500	55°42'56" 117°37'19"	15-21 22 55-	M M R	C S C	13,100 9.62	289,000 6-14-72	494 12-12-56	
07HA001	Peace R at Peace River, Alta.	8/	72,000	56°14'41" 117°18'46"	15-32,57-62 63-	M R	C C	63,800 12.03	514,000 7-11-65	5,250 12-6-61	Regulated since 1968 Data for pre-dam conditions.
07HC001	Notikewin R at Manning, Alta.	8/	1,810	56°55'25" 117°37'35"	61-	M	C	556 4.17	17,800 5-23-64	No flow Many days	
	ATHABASCA RIVER/ MACKENZIE RIVER:										
07AD001	Athabasca R at Entrance, Alta.	8/	3,920	53°22'37" 117°41'42"	15-21 22-23 24-39,55-60	M M M	C S C	6,610 22.9	45,000 6-2-36	250 4-26-37	
07AD002	Athabasca R at Hinton, Alta.	8/	4,000	53°24'45" 117°35'15"	61-	R	C	6,340 21.5	b44,800 6-13-72	382 3-14-63	
07AE001	Athabasca R nr Windfall, Alta.	8/	6,990	54°12'25" 116°03'45"	60-67 68-	M R	C C	9,060 17.6	75,200 7-10-65	828 3-30-64	

Table 2.1.2.5-2 (Continued)

Station[2/] no.	Name[4/]	Map[3/] reference	Drainage area (sq.mi.)	Location	Discharge records	Type[5/] of gage	Operation[6/]	Mean[7/] (cfs) (in)	Max.[7/] daily (cfs)	Min.[7/] daily (cfs)	Remarks
07AG001	McLeod R nr Wolf Creek, Alta.	2.1.2.2-22	2,480	53°39'15" 116°16'50"	15-23 24-31 57-68,70- 69	M M R R	C S C S	1,400 7.67	b80,000 6-8-54	f3 3-7-73	
07AG003	Wolf C at Hwy No. 16, Alta.	2.1.2.2-22	350	53°35'55" 116°16'15"	55-	M	C	130 5.04	b9,170 6-26-72	0.5 2-6-68	
07BA001	Pembina R bl Paddy Creek, Alta.	2.1.2.2-22	1,110	53°07'47" 115°19'30"	56-68 69-	M R	S S	f540 a6.6	b21,600 6-26-72	22 3-1-59	
07BB002	Pembina R nr Entwistle Alta.	8/	1,710	53°36'18" 115°00'14"	14-23,55-64 65-	M R	C C	682 5.42	b24,600 6-27-72	No flow Many days	
	NORTH SASKATCHEWAN RIVER/NELSON RIVER:										
05DB002	Prairie C nr Rocky Mtn. House, Alta.	2.1.2.2-23	318	52°16'20" 114°55'50"	22-25,51-60 61-62 63-	M M R	S C C	162 6.92	b4,080 6-26-72	f6 4-1-24	
05DB001	Clearwater R nr Rocky Mtn. House, Alta.	8/	1,210	52°20'50" 115°56'10"	14-31 44-52 53-	M M R	C S C	904 10.15	39,100 6-27-15	66 12-21-63	
05DC001	N Saskatchewan R nr Rocky Mtn. House, Alta.	2.1.2.2-23	4,220	52°22'51" 114°56'21"	13-31 44-52 53-	M M R	C S C	5,000 16.09	b145,000 6-27-15	271 11-23-70	Regulated since 1972
	SOUTH SASKATCHEWAN RIVER/NELSON RIVER:										
05AA023	Oldman R nr Waldron's Corner, Alta.	2.1.2.2-30	551	49°48'50" 114°11'00"	49-	R	C	494 12.18	b16,000 6-8-53	37 11-21-70	
05AB028	Willow C ab Chain L, Alta.	2.1.2.2-30	62.8	50°11'47" 114°12'46"	65-	R	C	40.1 8.67	1,600 6-25-69	0.05 1-17-70	

Table 2.1.2.5-2 (Continued)

Station[2] no.	Name[4]	Map[3] reference	Drainage area (sq.mi.)	Location	Discharge records	Type[5] of gage	Operation[6]	Mean[7] (cfs) (in)	Max.[7] daily (cfs)	Min.[7] daily (cfs)	Remarks
05BE006	Bow R bl Ghost Dam, Alta.	2.1.2.2-24	2,500	51°12'50" 114°36'40"	33-	R	C	3,030 16.5	b21,400 6-17-33	143 2-11-40	Regulated since 1929 by power dams
05BH009	Jumpingpound C nr the mouth, Alta.	2.1.2.2-24	219	51°09'16" 114°31'42"	65-69 70-	R R	S C	(c)	b4,870 6-29-69	No flow Many days	
05BJ004	Elbow R at Bragg C, Alta.	2.1.2.2-30	306	50°57' 114°34	35-48 49-66 67-	M R R	S S C	f310 14	b15,200 5-31-67	28 3-11-60	
05BK001	Fish C nr Priddis, Alta.	2.1.2.2-30	103	50°53'15" 114°19'30"	08-16,69- 56-68	M M	S C	42.1 5.56	b7,060 6-26-15	No flow Many days	
05BL019	Highwood R at Diebels Ranch, Alta.	2.1.2.2-30	300	50°24'20" 114°29'50"	50-	R	S	f320 14	b10,000 6-9-53	14 3-2-72	
05BL014	Sheep R at Turner Valley, Alta.	2.1.2.2-30	215	50°40'20" 114°15'40"	09-16 68-	M R	S C	192 12.1	b6,900 6-14-70	fNo flow Many days	
05AJ001	S Saskatchewan R at Medicine Hat, Alta.	8/	22,500	50°02'35" 110°40'40"	11-63 64-	M R	C C	7,400 4.47	b152,000 6-11-53	360 11-21-29	Regulated since 1929 Diversions since 1911
05AK001	S Saskatchewan R at Hwy. no. 41, Alta.	2.1.2.2-26	25,600	50°44'15" 110°05'45"	66-	R	C	7,230 3.84	b75,100 6-3-67	700 11-9-73	Regulated since 1929 Diversions since 1911
05CA001	Red Deer R nr Sundre, Alta.	2.1.2.2-24	954	51°42'00" 114°51'20"	50-68 69-	R R	S C	875 12.46	b23,100 6-18-65	115 3-1-63	
05CB002	L Red Deer R nr Water Valley, Alta.	2.1.2.2-24	178	51°30'45" 114°40'20"	61-68 69-	M R	S S	f88 6.7	b3,020 6-29-69	f0.1 Many days in 1963	
05CB001	L Red Deer R nr mouth, Alta.	8/	924	52°01'40" 114°08'20"	60-	M	C	180 2.65	5,310 6-17-70	0.1 12-29-61	
05CE006	Rosebud R bl Carstairs C, Alta.	2.1.2.2-25	316	51°25'00" 113°43'35"	57-60 61-	M R	S S	f13 0.6	1,460 4-2-69	No flow Many days	

Table 2.1.2.5-2 (Continued)

Station[2/] no.	Name[4/]	Map[3/] reference	Drainage area (sq.mi.)	Location	Discharge records	Type[5/] of gage	Opera-[6/] tion	Mean[7/] (cfs) (in)	Max.[7/] daily (cfs)	Min.[7/] daily (cfs)	Remarks
05CE005	Rosebud R at Redland, Alta.	2.1.2.2-25	1,400	51°17'35" 113°00'10"	51-	M	S	f60 0.6	6,240 4-9-71	No flow 3-1-70	Regulated
05HD036	Swiftcurrent C at Hwy no. 37, Sask.	2.1.2.2-28	567	49°53'40" 108°27'10"	55-59 60-	M R	S S	(c)	b3,280 4-10-55	No flow Many days	Regulated
	MILK RIVER/ MISSISSIPPI RIVER:										
11AC057	Frenchman R bl east end irrigation proj., Sask.	2.1.2.2-28	-	49°24'34" 108°36'05"	37-41,52-55 42-51,62-	M R	S S	(c)	b11,500 4-16-52	No flow Many days	Regulated since 1937
11AC051	Frenchman R bl Val Marie, Sask.	2.1.2.2-28	-	49°11'50" 107°41'20"	37,52-53 38-51,54-	M R	S S	(c)	b17,700 4-14-52	No flow Many days	Regulated since 1937
	KOOTENAY RIVER/ COLUMBIA RIVER:										
08NG005	Kootenay R at Wardner, B.C.	2.1.2.2-31	5,200	49°25'13" 115°25'10"	14-	M	C	7,240 18.91	64,200 5-27-68	840 1-12-63	
08NK005	Elk R at Phillips Bridge, B.C.	2.1.2.2-31	1,710	49°12'54" 115°06'38"	24-48 49-	M R	C C	2,740 21.80	33,500 5-24-48	206 1-1-31	
08NH006	Moyie R at Eastport, B.C. (nr Kingsgate)	2.1.2.2-31	570	48°59'58" 116°10'43"	15-16 29-	R R	C C	715 17.0	b9,400 5-20-54	30 1-2-37	

See next page for notes.

Table 2.1.2.5-2 (Continued)

2/ Water Survey of Canada station number.

3/ Figure number in this volume.

4/ ab - above   nr - near
bl - below   o - outlet

5/ M - Manual gage
R - Recording gage

6/ C - Continuous operation
S - Seasonal operation

7/ a - Estimated
b - Maximum instantaneous discharge
c - Insufficient data
d - Maximum monthly mean discharge
e - Minimum monthly mean discharge
f - From "Hydraulic and Geomorphic Characteristics of Rivers in Alberta".

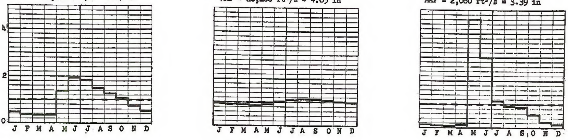
8/ Station is located beyond boundary of maps enclosed.

ADDITIONAL NOTES:

The number of years used to compute or estimate the mean discharge does not necessarily correspond to the full period of continuous gage operation shown. Means for seasonal records were estimated in a few cases. These estimates should be reasonably reliable, since winter flows were generally low.

The maximum daily discharges are shown for most stations because that was all that was published. Instantaneous discharges are shown when they are available. The maximum daily discharge may be considerably smaller than the instantaneous peak for small and intermediate streams. Maximum stages are not shown, but they may or may not have occurred at the time of maximum discharge. The highest stage might occur as the result of an ice jam.

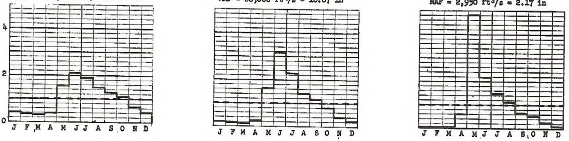
Caution should be used in interpreting minimum-flow figures. They are the lowest values published, but lower values may have occurred during periods of seasonal observations.



10KA001 - Mackenzie R at Norman Wells, N.W.T.
DA = 606,000 mi²
MAF = 288,000 ft³/s = 6.45 in

10JC003 - Great Bear R at O of Great Bear Lake, N.W.T.
DA = 56,300 mi²
MAF = 20,100 ft³/s = 4.85 in

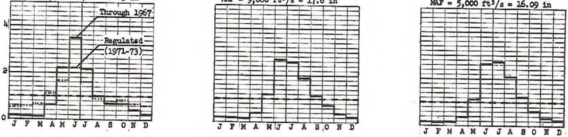
10BG001 - Willowlake R nr mouth, N.W.T.
DA = 8,330 mi²
MAF = 2,080 ft³/s = 3.39 in



10GC001 - Mackenzie R at Fort Simpson, N.W.T.
DA = 491,000 mi²
MAF = 224,000 ft³/s = 6.20 in

10ED001 - Liard R at Fort Liard, N.W.T.
DA = 85,700 mi²
MAF = 68,600 ft³/s = 10.87 in

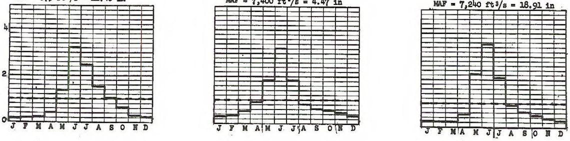
07OB001 - Hay R nr Hay River, N.W.T.
DA = 18,500 mi²
MAF = 2,950 ft³/s = 2.17 in



07HA001 - Peace R at Peace River, Alb.
DA = 72,000 mi²
MAF = 63,800 ft³/s = 12.03 in

07AE001 - Athabasca R nr Windfall, Alb.
DA = 6,990 mi²
MAF = 9,060 ft³/s = 17.6 in

05DC001 - N Saskatchewan R nr Rocky Mtn. House, Alb.
DA = 4,220 mi²
MAF = 5,000 ft³/s = 16.09 in



05CA001 - Red Deer R nr Sundre, Alb.
DA = 954 mi²
MAF = 875 ft³/s = 12.46 in

05AJ001 - S Saskatchewan R at Medicine Hat, Alb.
DA = 22,500 mi²
MAF = 7,400 ft³/s = 4.47 in

08NG005 - Kootenay R at Wardner, B.C.
DA = 5,200 mi²
MAF = 7,240 ft³/s = 18.91 in

Figure 2.1.2.5-3 Hydrographs showing ratio of mean monthly flow to mean annual flow

2.1.2.5-4, 2.1.2.5-5, and 2.1.2.5-6, taken from Thomas (1964) and Inland Waters Directorate (1973).

Arctic Ocean Drainage Basins

The streams and rivers of the Arctic Coastal Plain flow north and east to the Beaufort Sea across smooth, gravelly plains. These streams are swift and turbulent for short periods during the summer but are often frozen to the bottom during winter. However, because numerous springs have been reported in the watersheds along the Arctic Ocean (McCart, 1974), some streams along the proposed route may carry flow throughout the winter. For a given stream, winter flow may vary widely from season to season and may have large differences in discharge because of ice storage or flow entering or leaving unconsolidated alluvial deposits.
Typically, the coastal rivers display wide, shallow, braided channels subject to rapid and extensive lateral shifting. Some of the larger rivers are the Firth, Babbage, Blow, Fish, and Rat Rivers.

Breakup along the Arctic Ocean usually occurs in early June and freezeup begins in September. On the Arctic Coastal Plain all of the proposed route is in the continuous permafrost zone. Only the Firth River, which drains the largest basin on the Arctic coast west of the Peel River, is gaged (Table 2.1.2.5-2). Zero flow was reported in the Firth River in December of 1972 and 1973.

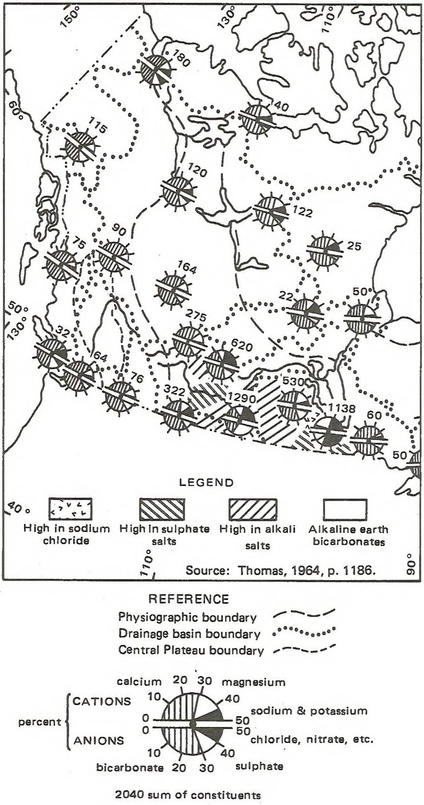
There is high probability of icings on the Malcolm, Firth, Fish, and Babbage Rivers. An icing (or aufeis) is a sheet of ice formed on a river flood plain during the winter by the successive freezing of water forced to the surface. These icings occur where the heat losses are large enough to constrict water passage below a snow and ice cover to the extent that all the flowing water cannot pass. The excess water escapes to the surface, overflows, and freezes. Icing initiation and growth is promoted by low winter temperatures, lack of a thick insulating snow cover, and winter disturbances such as compaction or removal of snow. Icings are usually unpredictable in size and development from place to place and particularly from year to year.

Generally, the peak flows in streams on the Arctic Coastal Plain occur as the result of snowmelt; however, on occasion, floods have been experienced after extreme summer rainstorms. A severe rainstorm in the Mackenzie Mountains in July 1970 caused major flooding in principal tributaries on the west side of the lower Mackenzie River (McKay, Fogarsi, and Spitzer in Task Force on Northern Oil Development, 1973).

Except for a small amount of data for the period 1971-72 reported by the Canadian Department of the Environment (Bryan, 1973), information was unavailable on water quality for the Arctic Ocean drainage basins. Tables 2.1.2.5-3 and 2.1.2.5-4 show representative water-quality data from that report. The dissolved-solids concentrations for streams sampled ranged from 44 to 253 mg/l. The higher concentrations of dissolved solids usually occur during the low-flow period in the winter. Most of the streams contain soft to moderately hard water of the bicarbonate type.

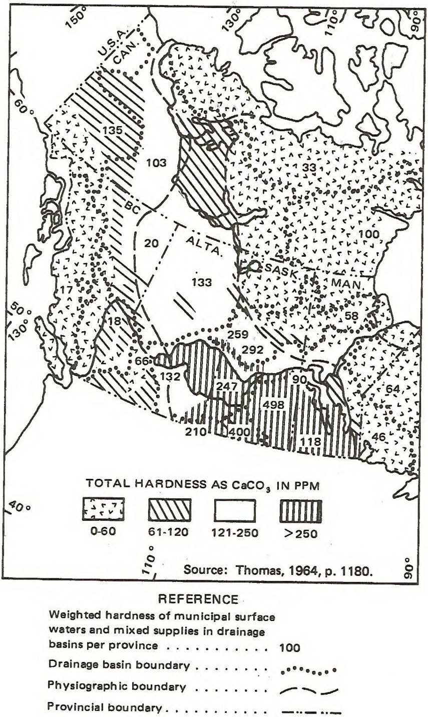
During the summer months dissolved oxygen is high, more than 9 mg/l in all streams (Bryan, 1973). During the winter dissolved-oxygen concentrations drop rapidly when the streams are covered by ice and probably are less than 1 mg/l in some streams.

Information is unavailable on the bacterial content of streams but it is assumed to be similar to that in streams in other sparsely occupied,



Source: Thomas, 1964, p. 1186.

Figure 2.1.2.5-4 Chemical quality of typical surface waters of western Canada


150°
130°
110°
90°
U.S.A.
CAN.
60°
135
103
33
BC
ALTA.
SASK.
MAN.
20
133
100
17
50°
130°
18
58
259
292
66
132
247
90
498
64
46
210
400
118
TOTAL HARDNESS AS CaCO3 IN PPM
0-60
61-120
121-250
>250
40°
110°
90°
REFERENCE
Weighted hardness of municipal surface waters and mixed supplies in drainage basins per province 100
Drainage basin boundary . . . .
Physiographic boundary . . . .
Provincial boundary . . . .

Source: Thomas, 1964, p. 1180.

Figure 2.1.2.5-5 Map of hardness of surface waters in western Canada

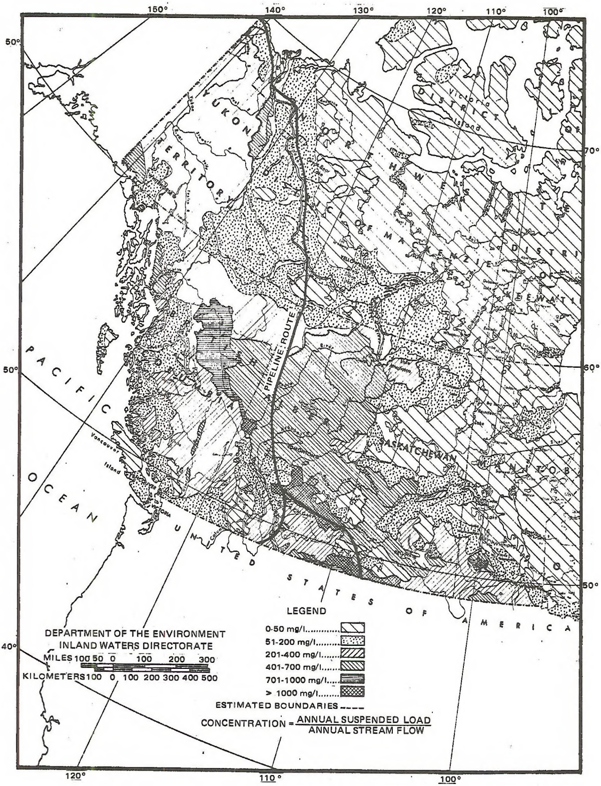


Figure 2.1.2.5-6 Suspended sediment concentration in rivers of western Canada, 1972

Table 2.1.2.5-3 Water quality data for northern Yukon Territory, July to October, 1971 1/

River or creek	Map reference (figures in this volume)	Date	Time	Temperature (°C)	Oxygen concentration (mg/1)	pH	Total alkalinity (mg/1)	Total Dissolved solids (mg/1)
Babbage R	2.1.2.2-4	July 26	1000	13	10	8.5	120	130
Babbage R	2.1.2.2-4	Aug. 11	1515	7	11	8.0	103	65
Blow R	2.1.2.2-4	Aug. 6	1500	11	9	6.8	34	60
Firth R	2.1.2.2-3	July 31	1030	10	11	8.5	137	80
Fish C	2.1.2.2-4	July 27	1230	14	10	8.5	-	150
Fish C	2.1.2.2-4	Aug. 17	1900	8	11	8.0	154	150
Malcolm R	2.1.2.2-3	July 29	1200	13	11	8.5	120	145
Rat R	2.1.2.2-5	Aug. 30	1430	6	-	6.8	17	44

1/ Adapted from Bryan, 1973, table 3, p. 16.

Table 2.1.2.5-4 Some physical and chemical characteristics of water bodies sampled March 16-26, 1972 1/

Map reference (fig. in this volume)	Water body	Location	Ice depth (cm)	Water depth (cm)	Water discharge (m^3/s)	Water temperature (°C)	Oxygen concentration (mg/l)	pH	Dissolved solids (mg/l)
2.1.2.2-3	Firth R (spring)	68°41' 140°50'	0	20	-	0.0	6	7.5	148
2.1.2.2-3	Firth R (open water)	68°41' 140°50'	0	50	0.9	0.0	11	7.5	111
2.1.2.2-3	Fish C (spring)	69°36' 140°07'	20	18	-	0.0	5	8.0	253

1/ Adapted from Bryan, 1973, table 8, p. 31.

undeveloped basins in the Arctic. The bacterial content is probably very low except in areas of local point sources of pollution at towns or villages.

Bryan and others (1973) note that the dominant periphyton organisms in the Beaufort Sea drainages are the diatoms Synedra, Hannaea, and Amphrora. The most common benthic invertebrates were Oligochaeta, Plecoptera, Chironomidae, and Tipulidae. Amphipoda were not a dominant component of the fauna, but were more common in coastal rivers and streams than in the Porcupine drainage. The number of organisms per square metre ranged from 11 to 1,331, with an average concentration of 245. The dominant organisms in the Firth River in order of abundance were Ephemeroptera, Plecoptera, Chironomidae, and Simuliidae; Chironomidae, Ephemeroptera, Plecoptera, and Simuliidae were most common in the Babbage River (Brunskill and others, 1973a, b).

Streamflow records from the Firth River indicate that breakup on the Arctic Coast can usually be expected in early to mid-June with channel ice disappearing by late June to early July (MacDonald and Lewis, 1973). Maximum water temperatures generally range from 11° C on the Firth River to 19° C on Campbell Creek near Inuvik in late July. Beginning in mid-August, water temperatures gradually drop, reaching the freezing point in late September.

Water temperatures from springs range from 2.5° C at Lupine Spring near Sagwon in Alaska (U.S. Geol. Survey, 1974) to 15° C at Cache Creek Spring near the mouth of the Mackenzie River (Environment Protection Board, 1974b). Springs with water temperatures ranging from -2.9° C to 54° C have been measured in northern Canada (Canadian Natl. Comm., 1974). Nauman and Kernodle (1973) measured 4° C summer diurnal surface-water fluctuations in the Alaskan Arctic Coastal Plain. There are no large lakes on the Arctic Coastal Plain; those shallow lakes that do exist have water temperatures which approach the ambient air temperature during the ice-free periods of the year.

Practically no data are available on the sediment characteristics of streams in this part of the proposed pipeline route. Estimates of suspended-sediment discharge during high flows have been made by Howard (in Environment Protection Board, 1974b, p. 177-204) which indicate that sediment concentrations are very low (less than 50 mg/l) in most streams. Davies (1974) shows data collected on the Firth River from June through September 1973 and information from an automatic pumping sampler for the period July 2-19, 1973 (Table 2.1.2.5-5). These data seem to indicate that sediment concentrations can be relatively high (more than 600 mg/l) during high runoff events. Based on the information available, streams draining to the Arctic Ocean appear to carry little suspended sediment during normal to low flows during open water. Generally, in the Arctic, for which information is available, suspended-sediment concentrations are usually very low under ice cover.

The water of all streams in this section of the proposed route probably is suitable for most uses; however, high turbidity and (or) color may occur in some streams.

Brunskill and others (1973a, b) give some water-quality information on lakes in the Mackenzie Delta region. Specific conductance values for these lakes ranged from 88 to 950 micromhos per centimetre. Dissolved-oxygen values ranged from 0 to near saturation. The lakes were nearly anaerobic under late winter ice cover but rapidly became supersaturated with oxygen in August and September, according to the report.

Table 2.1.2.5-5 Suspended-sediment data for station number 10MD001, Firth River near mouth 1/

(1) Computed daily mean concentrations - none (insufficient number of samples).

(2) Individual depth integrated samples.

Date	Sample concentration (mg/1)	Daily discharge (cfs)
June 5, 1973	41	4,550
July 3, 1973	1	2,200
Aug. 7, 1973	17	1,490
Sept. 18, 1973	7	1,390

(3) Samples taken by automatic pumping sampler.

Date	Sample concentration (mg/1)	Daily discharge (cfs)
July 2, 1973	64	2,780
July 3, 1973	45	2,200
July 3, 1973	11	2,200
July 4, 1973	4	2,040
July 5, 1973	21	2,340
July 6, 1973	23	3,370
July 7, 1973	272	3,040
July 8, 1973	512	2,560
July 9, 1973	172	2,230
July 10, 1973	119	1,910
July 11, 1973	48	1,960
July 12, 1973	84	2,150
July 13, 1973	154	2,940
July 14, 1973	238	3,040
July 15, 1973	239	3,310
July 16, 1973	342	4,500
July 17, 1973	629	4,570
July 18, 1973	466	6,000
July 19, 1973	614	6,880

[1] Adapted from Davies, 1974, p. 45.

In 74 dredge samples in the Mackenzie Delta region, the average number of benthic invertebrates was 1,392 per square metre; the range was 14 to 38,906. In the lower part of the delta the dominant organisms were Polychaeta, Amphipoda, Pelecypoda, and Gastropoda. In the upper reaches of the delta Chironomidae, Oligochaeta, Gastropoda, and Pelecypoda were the dominant organisms. Lakes in the Mackenzie Delta region were also sampled. The average number of species was 50 in clear lakes and 13 in silty lakes (Brunskill and others, 1973a, b). Brunskill and others (1973a, b) report on the order of 10 times as many organisms per square metre in clear lakes as in silty lakes.

Mackenzie River System

Lower Mackenzie River Basin

The streamflow regime of the Mackenzie River is described in records from hydrometric stations at Fort Providence, Fort Simpson, and Norman Wells (see table 2.1.2.5-2 and Figure 2.1.2.5-3).

Flow from the Mackenzie River enters the Arctic Ocean through a complicated network of channels and interconnected lakes that lie on the Mackenzie Delta. The distribution of flow through the delta is not well known, but investigations (R. J. Anderson and D. K. MacKay in Task Force on Northern Oil Devel., 1973, p. 71-109) demonstrate that the flow pattern is changed considerably from summer to winter by the ice cover. The entire area lies in the zone of continuous permafrost.

Maximum water levels usually occur during spring breakup with ice jams and rapid rises, but maximum discharge can take place later in June or July. The maximum mean-daily discharge known at Norman Wells occurred on July 25, 1972. Mean breakup dates are May 16 at Fort Simpson; May 17 at Norman Wells, and May 18 at Fort Good Hope. Flow from the Liard River is the main factor in the breakup process downstream from Fort Simpson (D. K. MacKay and J. R. MacKay in Task Force on Northern Oil Devel., 1973, p. 223-232).

Meteorological data in the Mackenzie Valley indicate that on the east side the frequency of extreme events is low, occurring mainly during the summer and not usually associated with thunder storms (K. Swami in Task Force on Northern Oil Devel., 1973, p. 537-570). Maximum water levels in lower reaches may be produced by backwater from the Mackenzie River. Unit runoff tends to be less in the northern than in the southern region.

Major streams on the east side of the river flow throughout the winter. The largest is the Great Bear River which has a drainage area of 59,000 square miles above the proposed pipeline crossing, three-fourths of which is water surface. The runoff pattern for this stream is shown in Figure 2.1.2.5-3. The small variation in extremes from the mean is due to the large area of lakes in this basin.

In addition to the Great Bear River, there are five streams entering the Mackenzie River from the east along the proposed route with watersheds larger than 1,000 square miles. Only one, Willowlake River, is gaged by the Water Survey of Canada. The seasonal runoff pattern for this stream is shown in Figure 2.1.2.5-3.

Magnitude and variability of low flow for the majority of small streams in the region are mostly unknown at this time. Observations in late winter (McCart, 1974) suggest that winter flow results primarily from springs and discharge from larger lakes, independent of basin size.

The Mackenzie River above its junction with the Liard River has a moderate range in flow because of the large storage in Great Slave Lake and the regulation of the Peace River by the W.A.C. Bennett Dam. At Fort Providence the maximum mean-daily flow is about twice the long-term annual mean. By contrast, at Fort Simpson, just below the Liard River, the maximum mean-daily flow is almost four times the long-term annual mean (Table 2.1.2.5-2). About one-third of the mean discharge of the Mackenzie River at Fort Simpson is contributed by the Liard River (MacKay, 1967).

There is a wide range in flow among basins of comparable size. For example, flow for the Trout River (drainage area 3,510 square miles) was zero for most of March and April 1972, but minimum daily flow for the Flat River (drainage area 3,280 square miles) was 300 cfs on March 11, 1973.

At the headwaters of streams originating in the Cordilleran Region on the west side of the Mackenzie basin stream water is soft to moderately hard (Tables 2.1.2.5-6, 2.1.2.5-7). As these streams traverse the Interior Plains, the mineral content, especially sulfate, increases. The eastern tributaries to the Mackenzie drain the Canadian Shield, and waters are much softer, and of bicarbonate type. The influence of the western tributaries on the Mackenzie River shows in a general downstream increase in dissolved-solids concentration (Thomas, 1964; Brunskill and others, 1973a, b).

On the basis of specific conductance data given in Brunskill and others (1973a, b) the dissolved-solids concentration of surface waters in the section of the proposed pipeline route from Fort McPherson to Fort Norman ranged from about 25 mg/l to more than 300 mg/l. The chemical composition and dissolved-oxygen content of streams in the section are similar to those described in the general comments above. The dissolved-iron concentration of waters throughout the basin is generally low (Reeder and others, 1972). The Mackenzie River, where it enters the delta, has an average dissolved-iron concentration of 0.04 mg/l. However, the dissolved-iron concentration of low-discharge rivers draining Cretaceous shales in northern Alberta reaches values as high as 0.71 mg/l (Reeder and others, 1972).

The dissolved oxygen in many rivers of the Mackenzie Basin is at less than 60 percent saturation when sediment transport is high during peak flows in spring and summer. Dissolved oxygen approaches saturation in the fall when suspended sediment and discharge are lower. In winter under ice cover the rivers are generally at less than 50 percent saturation and in some streams dissolved-oxygen concentration approaches zero.

Reeder and others (1972) indicate that the present sources of municipal and industrial pollution effect no significant changes in the water quality of the Mackenzie River drainage basin.

The dominant organisms in the main stream of the Mackenzie River below the Liard River are Chironomidae, Oligochaeta, Ephemeroptera, Plecoptera, and Tricoptera (Brunskill and others, 1973a, b). The data were obtained from both surber samples and artificial substrates. The range of organisms per square metre was 11 to 59,209 and the average was 2,732.

McCart (1974) described the benthic invertebrates from several streams in the vicinity of Norman Wells, Northwest Territories. Chironomidae, Plecoptera, and Ephemeroptera were the more common organisms in Prohibition Creek. In June, Simuliidae, Chironomidae, and Ephemeroptera were the more abundant in Maida Creek, but in August the Ephemeroptera were replaced by Plecoptera. Raspberry Creek was dominated by Chironomide, Tricoptera, and Simuliidae; Oscar Creek by Ephemeroptera and Chironomidae; and Ruby Creek by Ephemeroptera, Plecoptera, Chironomidae, and Simuliidae.

Table 2.1.2.5-6 Water-quality data for Mackenzie mainstem rivers and streams, 1971-72 1/

River or Stream	Map reference (figures in this volume)	Conductivity (μmho/cm^{-1})	Temperature (°C)	O_2 (moles/m^{-3})	pH
Arctic Red R	2.1.2.2-5	150-530	-1.4-18	0.33-0.37	7.3-8.1
Blackwater R	2.1.2.2-11	150-460	2.5-16	0.56	7.8-8.2
Brackett R	2.1.2.2-11	250-450	8.8-21	0.28-0.32	7.7-8.3
Great Bear R (Great Bear L)	2/	93-140	3.0-9.0	-	7.6-8.1
Great Bear R (Brackett R)	2.1.2.2-11	110-170	0.5-7.5	0.35-0.39	7.6-7.7
Hanna R	2.1.2.2-10	180-220	5.0-9.0	-	7.8-7.8
Hare Indian R	2.1.2.2-9	230-660	0.5-17	0.28-0.36	7.3-8.2
Jackfish C	2.1.2.2-9	230	12	-	8.4
Jean Marie C	2/	160-580	0.1-22	0.19-0.39	7.6-8.5
Liard R (Fort Liard)	2/	93-390	0.0-14	0.19-0.50	7.8-9.0
Liard R (Mackenzie R)	2.1.2.2-14	100-440	-0.5-19	0.16-0.34	7.7-8.7
Mackenzie R (Fort Providence)	2/	160-240	-0.2-17	0.22-0.39	7.3-8.2
Mackenzie R (above Liard R)	2.1.2.2-14	110-290	-0.1-18	0.17-0.49	7.7-8.6
Mackenzie R (Wrigley)	2.1.2.2-12	155	10	-	7.8
Mackenzie R (Norman Wells)	2.1.2.2-10	150-330	0.1-16	0.23-0.33	7.7-8.2
Mackenzie R (Fort Good Hope)	2.1.2.2-9	150	10	-	7.7
Mackenzie R (Arctic Red R)	2.1.2.2-5	200-220	8.3-18	0.30-0.34	7.3-7.9
Martin R	2.1.2.2-14	140-580	0.0-21	0.09-0.39	7.5-8.4
Peel R	2.1.2.2-5	<40-310	0.2-18	0.16-0.36	7.0-8.1
Petitot R	2.1.2.2-16	140-380	13-18	-	8.0-8.3
Redstone R	2.1.2.2-11	150-800	-0.2-14	0.19-0.38	7.7-8.3
Saline R	2.1.2.2-11	760-2500	6.0-20	0.53	7.8-8.4
S Nahanni (Virginia Falls)	2/	150-350	0.0-10	0.16-0.43	7.8-8.0
S Nahanni (Clausen C)	2/	110-260	5.0-13	0.50	7.8-8.1
Trout R	2.1.2.2-15	85-170	6.3-20	0.29-0.39	7.5-8.2
Willowlake R	2.1.2.2-13	59-2100	0.0-21	0.15-0.29	7.3-8.1

1/ Adapted from Brunskill and others, 1973b, table IIa, p. 147.
2/ Station is located beyond boundary of maps enclosed.

Table 2.1.2.5-7 Rates of transport of dissolved elements from Mackenzie watersheds 1/

Watershed	Ca	Mg	Na	K	SO_4	Cl	HCO_3
Western tributaries of the Mackenzie	164-282	52-156	13-42	4.7-9.2	55-208	6.3-17	498-770
Eastern tributaries of the Mackenzie	42-94	24-32	17-155	2.1-2.3	13-21	14-78	123-124

Watershed	TDP	TDN	Si	Reference
Western tributaries of the Mackenzie	0.31-0.66	2.1-4.8	9-19	Brunskill and others, 1973 a,b
Eastern tributaries of the Mackenzie	0.036-0.34	0.80-1.1	1.1-30	Brunskill and others, 1973 a,b

[1] Adapted from Brunskill and others, 1973a, table XXI, p. 85.

Brunskill and others (1973a) compared the mean number of invertebrates per artificial substrate sampler in six rivers flowing into the Mackenzie from the east and six from the west (Table 2.1.2.5-8). The mean number of organisms in the eastern rivers was significantly higher. They also found the species composition to be different. Tipulidae were present in most of the western rivers but were generally absent from rivers entering from the eastern side. The percentage of Simuliidae increases in a southerly direction on the western side; however, the eastern rivers showed low percentages of these insects at northern and southern extremes of the study area with increased percentages in the central area near Norman Wells.

Brunskill and others (1973a, b) found the fauna of the tributaries of the Peel and Arctic Red Rivers to be impoverished. The range was 0 to 721 organisms per square metre. The lower standing crops were also encountered in the large turbid rivers such as the Arctic Red and Peel Rivers.

The Peel River and main stem of the Mackenzie River carry relatively large amounts of suspended sediment during most of the open-water season. During 1973 the Peel River above Fort McPherson had suspended-sediment concentrations ranging from 198 to 1,900 mg/l (Table 2.1.2.5-9). The Mackenzie River suspended-sediment concentration ranged from 64 to 679 mg/l. Concentrations in the Peel River were in excess of 500 mg/l during most of the open-water season during 1973, and in excess of 100 mg/l in the Mackenzie (Davies, 1974). Brunskill and others (1973a, b) show a suspended-sediment concentration of 1,800 mg/l for the Mackenzie River at Norman Wells. No date of collection is given. This same report shows minimum concentrations of less than 5 mg/l for both the Peel and Mackenzie Rivers. It is assumed that these probably represent low flow during the winter, although no dates are given.

Data from Brunskill and others (1973a, b) indicate that both the Hare Indian River and the Great Bear River transport much smaller amounts of suspended sediment. Suspended-sediment concentrations for these two rivers ranged from less than 1 to about 100 mg/l.

The Mackenzie basin between Fort McPherson and Fort Norman has water temperature characteristics similar to those of the Arctic Coastal Plain. Maximum summer water temperatures of 18° C on the Peel River, 18° C on the Mackenzie River, and 17° C on the Hare Indian River have been measured (Brunskill and others, 1973a, b). Great Bear Lake had a measured July surface temperature of 9° C, which should be very close to the mean annual air temperature (Davies, 1974; Reeder and others, 1972).

During low flows the tributaries to the Mackenzie River between Fort Norman and Fort Simpson, especially Willowlake River, may have a higher dissolved-solids concentration than that described above for other eastern tributaries. Brunskill and others (1973a, b, p. 148-159) show a conductivity of 2,100 micromhos per centimetre for Willowlake River and relatively high concentrations of sodium and chloride. The increased mineralization probably results from ground-water inflow.

Davies (1974, p. 44) gives a computed suspended-sediment record for Willowlake River at its mouth for the open-water season of 1973. Suspended-sediment concentrations were less than 50 mg/l except for one high runoff event in May when they reached 160 mg/l. Brunskill and others (1973a, b) give the following maximum water temperatures for Mackenzie basin streams between Fort Norman and Fort Simpson: Blackwater River 16° C, Mackenzie River near Norman Wells 16° C, and Hare Indian River 17° C. A maximum surface temperature was measured on Willowlake River discharging from Willow Lake of 21° C (Brunskill and others, 1973a, b).

Table 2.1.2.5-8 Mean number of invertebrates per artificial substrate in rivers of similar latitude in eastern and western drainages into the Mackenzie River 1/

EAST DRAINAGE			WEST DRAINAGE		
River	Latitude	Mean number	River	Latitude	Mean number
Rabbitskin R	61°47'N	817.3	Liard R at Manners C	61°46'N	40.0
Harris R	61°52'N	642.0	Liard R at Fort Simpson	61°50'N	146.8
Trail R	62°06'N	1,400.0	Martin R	61°55'N	461.5
Francis C	65°12'N	150.3	Loon C	65°14'N	244.7
Tsital Trein C	67°29'N	152.7	Babaluk Br	67°28'N	15.7
Pt. Separation II	67°39'N	120.0	No Name 9	67°34'N	39.0

[1] Adapated from Brunskill and others, 1973a, table I, p. 24.

Table 2.1.2.5-9 Ranges of concentrations of total suspended sediment and Secchi visibility for major Mackenzie mainstem rivers and streams, 1971-72 1/

River or Creek	Map reference (figs. in this vol.)	Suspended sediment (grams m^{-3})	Secchi depth (m)
Arctic Red R	2.1.2.2-5	0.79-790	0.08-0.28
Blackwater R	2.1.2.2-11	0.52-47	>1->1.2
Brackett R	2.1.2.2-11	16-33	0.4-0.6
Great Bear R (Great Bear Lake)	2/	0.02-0.25	>4.0->4.0
Great Bear R (Brackett R)	2.1.2.2-11	2.3-6.8	2.2->2.0
Hanna R	2.1.2.2-10	180-2,100	0.09
Hare Indian R	2.1.2.2-9	<0.5-99	1.3-~2.0
Jackfish C	2.1.2.2-9	6.2	>0.3
Jean Marie C	2/	<0.20-4.3	0.61->1.0
Liard R (Fort Liard)	2/	3.3-560	0.06-0.28
Liard R (Mackenzie R)	2.1.2.2-14	0.36-1,100	>0.02-0.60
Mackenzie R (Fort Providence)	2/	2.3-7.5	0.50->1.0
Mackenzie R (above Liard R)	2.1.2.2-14	7.7-230	0.23-1.0
Mackenzie R (Wrigley)	2.1.2.2-12	62	0.38
Mackenzie R (Norman Wells)	2.1.2.2-10	3.5-1,800	0.07-0.40
Mackenzie R (Fort Good Hope)	2.1.2.2-9	190	0.12
Mackenzie R (Arctic Red R)	2.1.2.2-5	65-1,400	0.02-0.17
Martin R	2.1.2.2-14	0.41-120	0.23->1.0
Peel R	2.1.2.2-5	0.24-580	>0.05-0.23
Petitot R	2.1.2.2-16	12-150	0.35-~1.5
Redstone R	2.1.2.2-11	39-1,400	<0.02-0.28
Saline R	2.1.2.2-11	0.81-270	~0.10->2.0
S Nahanni (Virginia Falls)	2/	0.66-200	0.15-1.1
S Nahanni (Clausen C)	2/	18-500	~0.10-0.80
Trout R	2.1.2.2-15	0.72-12	~0.4->1.5
Willowlake R	2.1.2.2-13	1.3-100	0.52->1.5

1/ Adapted from Brunskill and others, 1973b, table VIa, p. 167.
2/ Station is located beyond boundary of maps enclosed.

The proposed pipeline route crosses the upper reaches of the Petitot River, and the Trout River. The small amount of data available (Dryen, Sutherland, and Stein, 1973; Brunskill and others, 1973a, b) indicates that the water in these streams is soft to moderately hard. The Trout River has a lower dissolved-solids concentration than the Liard River or the Petitot River (Brunskill and others, 1973a; b).

The suspended-sediment concentration of the Mackenzie River above the Liard River ranges from 50 to 300 mg/l, increasing downstream to 700 to 1,000 mg/l in the delta area (Stichling, 1974, Figure 6). Below and including the Liard River, streams transport large amounts of suspended sediment in a short open-water season, particularly in June and July. The data available for the Trout River indicate that it is a clear stream, the maximum reported sediment concentration being 29 mg/l (Davies, 1974). The western tributaries generally have greater velocities and discharges than the eastern tributaries of the Mackenzie River and are generally clear and transport only small amounts of suspended sediment (Brunskill and others, 1973b, appendix IX, table VI).

Upper Mackenzie River Basin

The Hay, Peace, and Athabasca River basins are the principal subbasins to be crossed by the proposed route. There are only two short-term stream-gaging stations in the Hay River basin near the proposed route, on Sousa Creek and Chinchaga River (Table 2.1.2.5-2). The basin has low relief, generally poor drainage, considerable muskeg, and is near the southern limit of permafrost. There are numerous small lakes, and the streams have low gradients. The seasonal runoff pattern for Hay River near the mouth is shown in Figure 2.1.2.5-3. The Sousa Creek record indicates that summer-rain flood peaks can occur in addition to spring-breakup and snowmelt peaks. The Chinchaga River is the largest tributary of the Hay River basin which would be crossed by the proposed route. Ice breakup occurs in late April, and the river starts to freeze in late October.

Along the proposed route the drainage characteristics improve and runoff increases as the route approaches the Peace River. The streamflow records on Notikewin River are indicators of the streamflow magnitudes and variabilities to be expected in the rivers with headwaters close to the proposed route.

The Peace River is the largest river that the proposed route will cross in Alberta. The drainage area above the suggested crossing is about 70,000 square miles. However, the W.A.C. Bennett Dam has regulated flow since 1967. Depending upon policy followed in operating the reservoir above the dam, peak flows downstream may be reduced significantly. Prior to the building of the dam, there was a 5 percent probability that a five-day mean discharge of 510,000 cfs or greater could occur in any given year. Under the reservoir operating policies postulated by Coulson and Adamcyk (1969, tables 1 and 2), the five-day mean discharge with a 5 percent chance of occurrence in any given year would be 360,000 cfs or greater. The effect of regulation is shown in Figure 2.1.2.5-3. A maximum daily discharge of 497,000 cfs occurred on June 14, 1972. The maximum daily discharge prior to regulation was 514,000 cfs on July 11, 1965.

The other proposed major crossings in the Peace River basin are on the Smoky and Little Smoky Rivers. A comparison of streamflow statistics in Table 2.1.2.5-2 of the comparably-sized Wapiti and Little Smoky Rivers illustrates the difference in magnitude of peak flows and runoff in those streams that are mostly in the mountains and those that are mostly on the plateau, respectively.

After crossing the Peace River and Smoky River in the Peace River Lowlands, the proposed route climbs to the moderately well-drained Alberta Plateau and crosses the Athabasca River. The Athabasca River has been gaged since 1960 near Windfall, downstream from the proposed route. There are also longer records from stations about 60 miles upstream from the proposed route. The river has significant flow from headwater glaciers, which causes increased summer flows as shown in Figure 2.1.2.5-3. The proposed route then begins to cross the Alberta Plain. The McLeod and Pembina Rivers have been gaged near the indicated crossings on the proposed route (Table 2.1.2.5-2).

Specific conductance values are reported by Thomas (1964) for the Peace River at Peace River for a three-year period of record. Conductance values ranged from 185 to 500 micromhos per centimetre.

Konopasek (undated) reports water-quality information for the Athabasca and McLeod Rivers below the proposed route crossing for the winter months (November 1971 to February 1972). He states that there is no serious problem with water quality in these two rivers. Biochemical oxygen demand did not exceed a limit which would create a dissolved-oxygen content of less than 6.0 mg/l in any sample taken during that summer. All coliform bacteria samples collected during that period registered values within the surface-water quality standards of the Province of Alberta.

Daily records of suspended sediment for Peace River at Peace River for 1968 (Water Survey of Canada, 1968a) are reported by the Inland Waters Branch. Suspended-sediment concentrations generally were less than 60 mg/l during the winter. During high flows in May and June concentrations reached values greater than 7,000 mg/l. Concentration values as low as 25 mg/l are reported during low-flow periods in September.

Sediment data for the Athabasca River below McMurry for 1969 (Water Survey of Canada, 1969b) indicate that the river at that point carries practically no suspended sediment during winter periods (generally less than 5 mg/l). The maximum concentration reported during high flow was 3,520 mg/l in August 1969. Suspended-sediment concentrations were less than 100 mg/l for much of the open-water season.

Nelson River System

The proposed route traverses the upper reaches of the Saskatchewan River, a major tributary of the Nelson River by way of Lake Winnipeg in Manitoba. The North Saskatchewan River has been regulated by Bighorn Dam since 1972. Preregulation flow statistics are presented in Table 2.1.2.5-2 for a station upstream from the route, and the seasonal runoff pattern is shown in Figure 2.1.2.5-3. The proposed crossing is downstream from a major tributary, Brazeau River, which has been regulated by Brazeau Dam since 1963. Streamflow values for Clearwater River and Prairie Creek are representative of the smaller streams.

The proposed route south of Caroline Junction to Monchy remains in the Alberta Plain. It crosses the Red Deer, Little Red Deer, Rosebud, and South Saskatchewan Rivers, and Swift Current Creek. There is a gaging station on the Red Deer River near Sundre upstream from the proposed route and one downstream from the proposed route on the South Saskatchewan River at Highway No. 41. However, there is a longer record at the station at Medicine Hat on the South Saskatchewan River. Seasonal runoff patterns are shown in Figure 2.1.2.5-3 for this station. Ice breakup normally occurs in early April and freezing starts in mid-November.

The larger rivers crossed by the proposed route between Caroline Junction and the Continental Divide are the Red Deer and Bow. The seasonal runoff pattern for the Red Deer River is shown in Figure 2.1.2.5-3. Many of the other streams whose drainage basins are in the 100 to 300 square-mile range have been gaged near the proposed route. The route parallels the Rocky Mountain Foothills, then enters the foothills and crosses the Continental Divide. Records on Jumpingpound and Fish Creeks are representative of streams originating in the foothills. Records on Willow Creek and the Bow, Elbow, Highwood, Sheep, and Oldman Rivers are typical of streams in this basin which have their headwaters in the mountains. Bow River has significant flow from glaciers within its headwaters.

The headwater streams of the Saskatchewan Basin rise in the Rocky Mountains and are medium-hard bicarbonate water. According to Thomas (1964), inflow from springs and surface runoff from some headwater areas are relatively high in calcium and sulfate. The water in many tributaries increases in mineral content, hardness, and sulfate as the streams flow eastward (Masuda, 1971).

Masuda (1971) reports that dissolved oxygen in the North Saskatchewan River above Edmonton remained above 10 mg/l during the winter of 1970-71 except for the Brazeau River discharge where oxygen levels reached a low of 4.8 mg/l in January. Below Edmonton pollution levels increase as a result of industrial and municipal effluents (Masuda, 1971).

Shewchuk (1971) reports that the South Saskatchewan River is a clean water supply for existing and prospective users. Data collected during a winter survey in 1970-71 indicated that no unsatisfactory values occurred with respect to dissolved-oxygen, turbidity, pH, total hardness, chloride, oil and grease, or bacteriological constituents.

The Red Deer River, a tributary to the South Saskatchewan, experiences low dissolved-oxygen levels below the city of Red Deer (Masuda, 1971). A minimum value of 1.9 mg/l was reported at a site 52 miles below Red Deer in the winter.

The North Saskatchewan River transports very little sediment during the winter months, usually less than 10 mg/l. The concentration increases to more than 1,800 mg/l during May and June, 50 to 95 percent of the sediment is finer than 0.062 mm (Water Survey of Canada, 1968a, 1969b, 1970a). The suspended-sediment concentration of the North Saskatchewan River in its headwaters ranges from 50 to 200 mg/l, increasing to 400 to 700 mg/l downstream (Stichling, 1974). The South Saskatchewan River and its tributaries also have low sediment concentrations during the winter months, generally less than 10 mg/l. During May through July, concentrations increase greatly, with the highest concentrations (more than 10,000 mg/l) occurring in the Red Deer River. The maximum reported concentrations for the South Saskatchewan River below Red Deer River are more than 5,000 mg/l. Below Lake Diefenbaker reservoir, which acts as a sediment trap, the highest reported summer suspended-sediment concentrations on the South Saskatchewan River are approximately 700 mg/l. Below the confluence of the North and South Saskatchewan Rivers the average suspended-sediment concentrations range from 200 to 400 mg/l in the Saskatchewan River, gradually decreasing downstream as the sediment is trapped in various lakes and reservoirs (Stichling, 1974).

Seasonal water temperatures for the higher altitudes in the Upper Saskatchewan Basin are described as follows by the Water Survey of Canada:

> Immediately following breakup, water temperatures warm for approximately two months and then maintain a constant temperature

or perhaps even experience a slight drop, for a period of up to one month, after which the temperatures again rise until the peak in late July or August. A station exhibiting this phenomenon is the Clearwater River near Rocky Mountains House. It is felt that this temperature trend occurs when the higher elevation snow begins to melt thus tending to lower the stream water temperatures.

The maximum point observation made was 86°F. The temperature occurred on both Lee Creek at Cardston and Vermilion River near Mannville. The approximate mean maximums for these two rivers are 72°F and 70°F, respectively, as compared with the highest mean maximum of 75°F on the Little Red Deer River near the mouth. The maximum point observation on the Little Red Deer River was 80°F. With the exception of the Little Red Deer River near the mouth, all other rivers with approximate mean maximums of 70°F and over, lie in the extreme south and southwestern part of Alberta or in Saskatchewan.

The lowest maximum point observation made was 53°F on the North Saskatchewan River at Saskatchewan Crossing. This river also has the lowest approximate mean maximum temperature which is 47°F. The reason for this river being so cold is that the point of measurement is just below the headwaters which come off the Saskatchewan Glacier. In general, the majority of the colder temperatures are found at stations in the mountain regions with a warming trend occurring as the rivers flow eastward. The coldest temperature throughout the year on any river will, of course be 32°F (Water Survey of Canada, 1970b, pp. 5-6).

Mississippi-Missouri River System

Frenchman River Basin

The proposed route crosses the Frenchman River which drains into the Milk River, a tributary to the Missouri River, about halfway between the two long-term gaging stations on this river.

Flood data are presented in Table 2.1.2.5-2. The average March to October flow is about 70 cfs.

Columbia River System

Kootenay River Basin

The major rivers crossed by the proposed route in British Columbia are the Kootenay River and two of its tributaries, the Elk River and the Moyie River. The Kootenay River is a major tributary to the Columbia River. Table 2.1.2.5-2 presents information for stream-gaging stations near the proposed route. The terrain through the Rocky Mountains from the Continental Divide to the Elk River generally is rugged and the streams are small. The proposed route then crosses the Kootenay River in the flats of the Rocky Mountain Trench. The proposed route next crosses the Columbia Mountains and parallels Moyie River. Figure 2.1.2.5-3 shows the seasonal runoff pattern for the Kootenay River.

The suspended-sediment concentration on the Kootenay River ranges from less than 10 mg/l during the winter months to more than 600 mg/l during May and June (Water Survey of Canada, 1969b, 1970a). The range of suspended-sediment concentration for the Kootenay River in its headwaters is 2 to 400 mg/l decreasing to 0 to 50 mg/l at its confluence with the Columbia River (Stichling, 1974).

Ground Water

The following discussions concerning the ground-water resources along the proposed route are based on data that were available from various publications of both the private and government sectors of Canada. Reports submitted by the Applicant and publications of the Canadian Department of Energy, Mines, and Resources, the Alberta Department of the Environment, and other agencies were the primary sources of information.

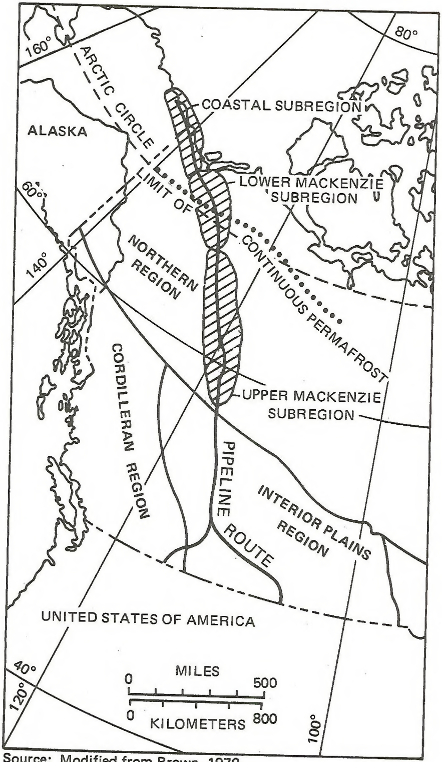
The proposed route may be divided into segments that cross each of three hydrologic regions: the Northern, the Interior Plains, and the Cordilleran (Brown, 1970) (Figure 2.1.2.5-7). The Northern Region is differentiated principally because of the overriding effect of permafrost on ground water. The Northern Region includes, from north to south, parts of the Yukon Coastal Plain, the Mackenzie Delta, and those subdivisions of the Interior Plains physiographic region within the permafrost area. The Interior Plains Region includes all of the plains region east of the Rocky Mountain front and south of the southern limit of discontinuous permafrost, extending to the Canada-United States border. In the Interior Plains Region the proposed pipeline route traverses the high plains of Alberta. About 100 miles south of Calgary the Kingsgate Delivery Line enters the Cordilleran Region at the Rocky Mountain front and continues in the Rocky Mountains to Kingsgate at the Canada-United States border. In all three regions, the proposed route is underlain by a layer of unconsolidated surficial deposits mainly of glacial origin that varies in thickness from less than 1 to more than 100 feet; deposits overlie a wide variety of sedimentary, igneous, and metamorphic rocks.

Ground water is unavailable for water supplies throughout most of the Northern Region owing to permafrost conditions. Ground water is generally available in the Interior and Cordilleran Regions.

The surficial water- and ice-bearing geologic materials underlying the proposed route can be differentiated by division into four major hydrogeologic units. These are: alluvium, glacial drift, bedrock, and undifferentiated soil materials. Where the proposed route crosses streams or abandoned stream channels, surficial deposits commonly consist of alluvium. These deposits are good aquifers where not frozen, and may contain large quantities of ground water.

The terrain along almost all of the proposed route was glaciated during Pleistocene time and, as a result, much of the route lies on glacial drift deposits. Drift may be composed of outwash, a good aquifer material similar to alluvium; till, a fair to poor aquifer; and lacustrine (lake) deposits many of which are fine-grained silts and clays and are very poor aquifers.

Bedrock may consist of clastic rocks, such as sandstone, which are fair aquifers; carbonate rocks, such as limestone, which are fair to good aquifers; or crystalline rocks, such as volcanic or metamorphic rocks, which generally are poor aquifers.



Source: Modified from Brown, 1970.

Figure 2.1.2.5-7 Ground-water regions of western Canada

Soil material, which includes the seasonally thawed zone (active layer), at and just below ground surface is probably the most important hydrogeologic unit in relation to the proposed route. These materials are not good aquifers, but do transmit surficial ground water and frequently contain ground ice. Water may move freely or be frozen as ice in this zone, depending on the season.

Ground Water in the Northern Region

The Northern Region may be divided into three geographic subregions: the Coastal, the Lower Mackenzie, and the Upper Mackenzie (Figure 2.1.2.5-7). The presence of continuous permafrost in the Coastal and Lower Mackenzie subregions and discontinuous permafrost in the Upper Mackenzie subregion causes ground water to be only seasonally present at very shallow depths. The temperature of permafrost underlying the surface increases from -15° C near the Arctic Ocean to just below 0° C near the southern boundary of the region (Brown, 1967; MacKay, 1967).

As a result of permafrost conditions, availability, recharge, movement, and discharge of ground water are profoundly different from conditions in warmer climates (van Everdingen, 1974). Permafrost acts as an impermeable barrier to the movement of ground water because the pore spaces within the zone of saturation generally are filled with ice. Recharge and discharge are thus limited to unfrozen zones (Williams, 1970).

According to Howard (in Environment Protection Board, 1974b, p. 197), "Ground water may occur in three different zones in permafrost: The thawed zone (active zone) above the permafrost in the Summer, the unfrozen zones within the permafrost (taliks), and the zone below the permafrost." In the thawed zone, ground water moves through the surficial materials penetrating deeper and deeper below the surface as thaw progresses during the summer months. In the continuous-permafrost zone (Figure 2.1.2.5-7), the thawed zone, or active layer, may be less than 1 foot in depth, but it increases in depth in a southerly direction so that in the discontinuous-permafrost zone near the southern limit of permafrost the active layer may be from several to 10 feet thick. The thickness of the active layer depends largely on the heat conductivity of ground cover, on the earth materials overlying permafrost, and on the mean annual ground-surface temperature. Movement of ground water in this zone begins in summer and continues well into the winter months and ceases when the winter surficial frost merges with permafrost at depth.

Significant quantities of water in unfrozen zones commonly occur in alluvium under and adjacent to large streams, in recently abandoned stream channels, in glaciofluvial material, and beneath lakes. In all cases the heat contained in the water in bed and bank storage, in transient flow, or in storage in lakes is sufficient to prevent the ground from freezing. Unfrozen ground-water bodies may be connected to the thawed zone at the surface and to subpermafrost ground water in saturated sediments at depth.

Ground ice in the form of wedges and lenses is common in permafrost areas. In the fine-grained deposits of the Mackenzie Delta and Coastal Plain, ground ice commonly occupies more than 50 percent of the upper 15 feet of surficial material. Within the soil-ice mass, the ice generally occurs as thin to very thick horizontal ice layers, as thin ice veins, or as vertical ice-wedge polygons. Ground ice can also occur in the coarser sedimentary materials in smaller quantities (CAGPL, 1974d). Less commonly, for example, near Fort McPherson, ground ice may be found in lenses more than 100 feet thick and 300 feet wide. The surface of these large masses of ice may be from 3 feet to 110 feet below the ground surface.

Recharge to the intrapermafrost (unfrozen zone) and subpermafrost (zone below the permafrost) ground-water zones in the continuous- and discontinuous-permafrost zones is mainly by seepage to the subsurface from streams and lakes. Lack of recharge from the surface to subsurface has resulted in the formation of a myriad of lakes in the semiarid Northern Region (Brandon, 1965). These lakes are perched above the permafrost layer.

Movement of ground water in unfrozen materials in the continuous- and discontinuous-permafrost zones depends on confining conditions. Surficial ground water in the saturated zone is unconfined and will flow downgradient. Ground water in unfrozen zones may be confined by nearly impermeable sediments or by overlying permafrost. It may thus be under pressure significantly greater than atmospheric and will move toward areas of lower hydrostatic pressure. Similarly, water in the subpermafrost zone is generally confined and will move toward areas of lower pressure.

Ground water is discharged by springs, as seepage, by evaporation, and by transpiration through vegetation. Indirect evidence of the occurrence of ground-water discharge includes seasonal variations in dissolved-solids concentrations in stream water, open water in streams in winter, aufeis deposits, and open-system pingos (van Everdingen, 1974).

During the winter, unless the ground-water discharge enters a perennial water body (stream or lake), ground water will eventually freeze at some distance downstream from its point of discharge, forming aufeis deposits (icings). Major examples of aufeis occurrence are found in the valleys of the upper Firth River, Babbage River, and Joe Creek (Table 2.1.2.5-10) (van Everdingen, 1974). Open water in winter below springs along the proposed route in the Beaufort Sea drainages extends from 0.75 to 1.9 miles downstream to a point where the water may freeze and form aufeis deposits, according to McCart (1974).

Ground water generally is not available along the proposed pipeline route in the continuous-permafrost zone. In the discontinuous-permafrost zone, many communities obtain ground water from wells in unfrozen aquifers near perennial streams and large lakes. Most of those wells are low in yield; they serve small population centers (Brandon, 1965).

Ground Water in the Interior Plains Region

In the Interior Plains Region of Alberta along the proposed route, most ground water is from a thick layer of surficial glacial deposits (drift). These deposits thicken from an average of less than 75 feet in the west to more than 1,000 feet in eastern Alberta. About 60 percent of the drift is till and about 40 percent is glacial-lake deposits. Bedrock is exposed in only a few places, mostly in deeply incised stream channels.

Table 2.1.2.5-10 Discharge rates, TDS 1/ contents, and water temperature for springs with associated open water and aufeis deposits 2/

Location of Springs	Discharge, l/sec.	TDS, ppm	Temp., °C	Open Water	Aufeis
Yukon Territory					
Fishing Branch	11,200 (t)	255	4.5 to 5.3	Yes	No
Upper Firth River	900 (t)	278	1.5	Yes	Yes
Joe Creek	30.4;470 (t)	195	4.0	Yes	Yes
Fish Hole Creek	69.7;898 (t)	185 - 205	4.0 to 4.5	Yes	Yes
Upper Babbage River	81.0;1400 (t)	187 - 247	4.5 to 4.8	Yes	Yes
Crow River	41.8	222 - 270	2.0 to 5.0	Yes	Yes
Fish Creek	12.4;120 (t)	250 - 253	2.0 to 3.0	Yes	Yes
"New" Creek	62.2;355 (t)	319 - 409	2.0 to 3.0	Yes	Yes
Arctic Islands					
Gypsum Hill, Axel Heiberg Island	3.7	75083 - 75812	-2.9 to +6.7	Yes	Yes
District of Mackenzie					
Cache Creek	345 (t)	2585 - 3158	15.0 to 17.0	Yes	Yes
Prohibition Creek	3.2	1597	7.5	Yes	Yes
Vermilion Creek	77 + 90	1223 - 2198	4.0 to 8.0	Yes	Yes
"Birch Island" Creek	129 (t)	625	3.5	Yes	Yes
Creek N. of Ochre River	19.4;150 (t)	427	4.0	Yes	Yes
Smith Creek	38.4	685	3.0	Yes	Yes
Blackwater River	28.3 + 236	634 - 895	2.5 to 3.0	Yes	Yes
Willowlake River 4 miles above mouth	12.7 + 62.8	2271 - 2295	9.5 to 12.0	Yes	No

[1] Total dissolved solids

[2] From van Everdingen, 1974, p. 88.

(t) denotes combined discharge from group of springs.

For about 200 miles south of the northern boundary of the region, rare discontinuous permafrost is found where thick ground cover, such as peat, is present. In these areas the permafrost temperature is very close to 0° C, and ground water and isolated lenses of ground ice may be near the surface. Farther south the climate is semiarid. Evapotranspiration rates are high, and surface water easily infiltrates the permeable subsurface deposits. Under these conditions, the zone of ground-water saturation may be far below the land surface.

The potential yield from ground water in southern Alberta is estimated at about 5,330 cfs, whereas ground-water use is estimated at 75 cfs, or only 1.4 percent of potential basin yield (Nielsen and Lorberg, 1971). Most of the shallow ground-water development occurs in the till deposits, which are poor aquifers. Many wells provide barely enough water for domestic use. Sixty percent of all farm-water supplies are obtained from shallow wells that yield 5 gpm or less from till (Meyboom, 1967). However, some wells developed in outwash deposits or recent alluvial deposits along stream courses yield from 10 to 750 gpm (Nielsen, 1969). Most of the municipalities and industries obtain their water from sandstone, or from the alluvial sands and gravels (Nielsen and Lorberg, 1971).

Ground Water in the Cordilleran Region

The proposed route in the Cordilleran Region generally is underlain by crystalline rocks and folded Tertiary and Cretaceous sedimentary rocks. Unconsolidated deposits are limited primarily to intermontane valleys and basins. Some permafrost is present in the higher mountain country. Ground-water flow gradients are high in the steeply sloping mountain country, and springs are common.

Ground water normally is present in usable quantities in alluvial deposits of the river valleys. The zone of saturation may be close to the surface in alluvium adjacent to perennial streams. Ground-water supplies have not been extensively developed in this region, but large quantities of water may be obtainable.

Water Quality

Information on ground-water quality in the Northern Region is limited to water samples from the springs and the few wells near the proposed pipeline route. Table 2.1.2.5-11, Summary of Chemical Quality for Selected Springs and Wells, shows the general chemical quality of certain spring and well waters in the permafrost zone. Most of the springs in the Arctic Slope Region are calcium bicarbonate in type and have low dissolved-solids concentrations. However, Cache Creek has sodium-chloride-type water and relatively high dissolved-solids concentrations. The water from Cache Creek Spring is similar to that at Roche qui Trempe a l'Eau Spring 2 miles downstream from Wrigley (McCart, 1974).

Calcium-sulfate-type water occurs on Old Fort Island and in Willowlake River. Water temperatures for the springs range from 1.5° C to 15.0° C (Mutch and McCart, 1974; Brandon, 1965; van Everdingen, 1974).

Water from some of the shallow wells in the settlements in the permafrost zone is a calcium- or magnesiumbicarbonate-type with low

Table 2.1.2.5-11 Summary of chemical quality for selected springs and wells in the vicinity of the proposed route

SPRINGS

Name	Fish Creek[1]		Firth River[1]				Joe Creek[1]		Babbage River[1]				Roche-qui-trempe-a'l'eau[2]			Old Fort Island[2]	Willow-lake River[3]	Cache Creek[3]
Site	-	-	1	2	2	2	-	-	A	B	Main	Main	A	B	C	-	8 mi ab mouth	-
Date	11-8-72	4-18-73	11-9-72	11-9-72	4-18-73	6-28-73	10-5-72	11-9-72	11-9-72	9-5-72	11-10-72	6-27-73	8- -60	8- -60	8- -60	8- -60	6-22-73	6-26-73
Discharge (m^3/s)	.14	.01	-	.43	.36	-	-	.56	-	-	1.7	-	-	-	-	-	-	-
Temperature (°C)	3.0	2.0	1.5	2.5	2.0	3.0	4.0	4.0	4.5	4.5	4.5	4.8	-	-	-	-	9.5	15.0
pH	(7.8)	(8.0)	(8.0)	(8.2)	(8.0)	(7.4)	(8.4)	(7.7)	(8.2)	(8.0)	7.8	(7.5)	7.7	7.8	7.7	7.9	7.4	7.6
Conductivity	(295)	311	(310)	(520)	454	(410)	238	(230)	81	(192)	(290)	(285)	17,981	17,511	17,880	1,535	2,380	4,800
Dissolved solids, sum (mg/l)	253	250	278	409	334	312	195	. 195	53	187	244	247	12,556	12,000	12,766	1,180	2,082	2,941
Water type	← $CaHCO_3$ →												← NaCl →			$CaSO_4$	$CaSO_4$	NaCl

WELLS

Town	Fort Norman[2]	Wrigley[2]	Fort Simpson[2]		
Site	-	-	H.B.Co. house	R.C. mission	Airport
Date	8- -60	8- -60	8- -60	8- -60	8- -60
Depth of well (ft)	20	150	40	48	26
Temperature (°C)	-	-	-	-	-
pH	7.7	8.1	8.0	8.0	8.2
Conductivity	1,346	554	9,043	1,063	795
Total hardness (mg/l)	732	308	878	464	454
Dissolved solids, sum (mg/l)	858	317	5,174	652	465
Water type	$MgHCO_3$	$CaHCO_3$	NaCl	$CaHCO_3$	$CaMgHCO_3$

1 McCart, 1974
2 Brandon, 1965
3 van Everdingen, 1974

concentrations of dissolved solids and low total hardness. One well in Fort Simpson, however, has a sodium-chloride-type water (Brandon, 1965).

Ground water in the surficial deposits south of the permafrost zone, in the more arid parts of Alberta, generally is a calcium-sulfate-type water that is very hard and high in dissolved minerals (Brown, 1967). In southern and eastern Alberta, dissolved-solids concentrations exceed 2,500 mg/l. However, in the west where precipitation is greater, the water has a low dissolved-solids concentration.

2.1.2.6 Vegetation

The proposed route traverses regions of extreme diversity in terms of climate, physiography, and substrate materials and conditions. The route in Canada (Figures 2.1.2.6-1 and 2.1.2.6-2), continued from similar terrain in Alaska, begins on the narrow coastal plain of the Yukon and at the Canadian gas field on the Mackenzie Delta, and crosses vast plateaus and interior plains before the branch pipeline to Kingsgate passes through the Rocky Mountains of southern British Columbia.

Essentially all regions adjacent to the proposed route were glaciated during the Wisconsin Stage of the Pleistocene and glacial features such as moraines, till plains, eskers, drumlins, and glacial outwash plains are common features. This historic event provides the broad array of boulders, gravels, sands, silts and clays, both sorted and in innumerable mixtures, which together with bedrock, principally at higher altitudes of the mountains, constitute the soil parent materials on which vegetation occurs. Extensive organic deposits have accumulated in post-Wisconsin time and further contribute to the variety of materials on which current vegetation develops.

Permafrost in some degree characterizes the entire area within the Yukon and Northwest Territories. Continuous permafrost extends southward about to Fort McPherson, becomes increasingly discontinuous and still common as far as Fort Simpson, and from there becomes more scattered until essential disappearance in northern Alberta, excepting at higher elevations of the Rocky Mountains. Permafrost, and especially the thickness of the overlying active layer resulting from warm season thaw, has an important bearing on vegetation type and distribution. The large variations in all aspects of the abiotic environment coupled with different species assemblages and varying ages of surfaces have produced very complex vegetation patterns further complicated over much of the proposed route by recurrent fires, both natural and of human origin. The secondary vegetation which results from burning is widely displayed in all stages of succession.

The plant species, which have reached Canada by migration at various times in the past, have been sorted and sifted by the environment and have survived, or not, depending upon whether their biological requirements were met or their environmental tolerances exceeded. The successful species have become components of communities of plants of similar environmental requirements. The patterns or mosaics of communities repetitively demonstrate the cause and result relationships between the available species and the total biotic and abiotic environment. Northward through these communities there is a reduction in the number of kinds of organisms and, therefore, in the possible community complexity. The Tundra, for example, is ecologically simpler than the Forest-Tundra--it has fewer biological components and also less diversity of habitats.

Major Plant Formations, Associations and Communities

The formation constitutes the major unit of classification of plant communities and is itself composed of many associations and communities at other levels of social organization in a hierarchical system. The associations are very unequally known over the proposed route and it would be misleading to attempt a uniform system of classification implying knowledge that does not yet exist. Below the level of the formation vegetation units will be discussed simply as communities. The term community implies social or ecological organization but is noncommital with respect to rank in a system of vegetation classification.

The proposed route would cross the following seven formations (Figure 2.1.2.6-1) derived with modification from the "Formation Type" classification of the National Atlas of Canada (Fremlin, 1974):

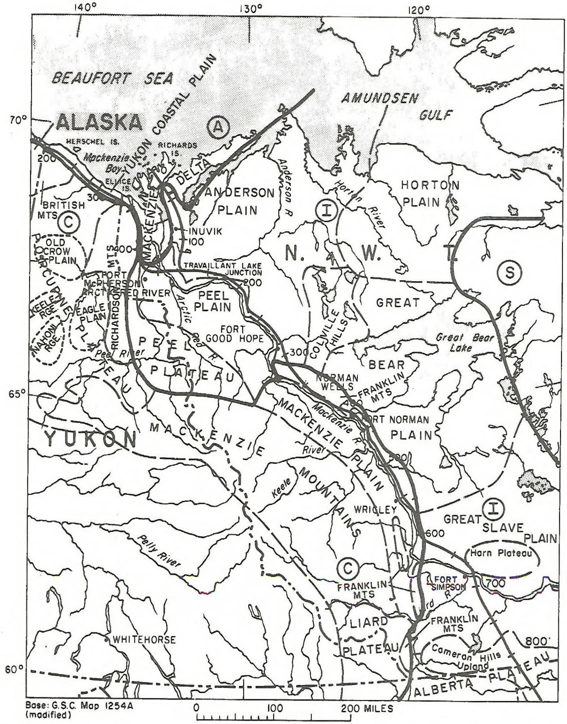
- Tundra
- Forest-Tundra
- Boreal Forest
- Subalpine Forest
- Interior Wet Belt Forest
- Parkland
- Grassland

Yukon and Northwest Territories

Vegetation along the proposed route north of 60° N latitude (Figure 2.1.2.6-2) has been divided (Hernandez, 1974) into five zones (Figure 2.1.2.6-3): 1) Boreal Forest; 2) Forest-Tundra; 3) Alpine Tundra; 4) Herbaceous Coastal Tundra; and 5) Low Shrub-Heath Tundra. As interpreted here these zones comprise the Boreal Forest, Forest-Tundra and Tundra Formations. This description of the vegetation is largely drawn from Hernandez and Environment Protection Board (1974c, v. 3). Both Hernandez and CAGPL (1974d) are sources for pertinent bibliography, including several studies sponsored by the Applicant and the Canadian government for the pipeline corridor (i.e., Crampton, 1973; Dabbs and others, 1974; Heginbottom, 1973; Hernandez, 1973; Hettinger and others, 1973; Janz, 1972, 1973; Lavkulich, 1972; Reid, 1974; Strang, 1973; Wein, 1971, 1972; and Younkin, 1972, 1973). Also see Bliss and Peterson (1973); Bliss and others (1973); and Wein and Bliss (1973).

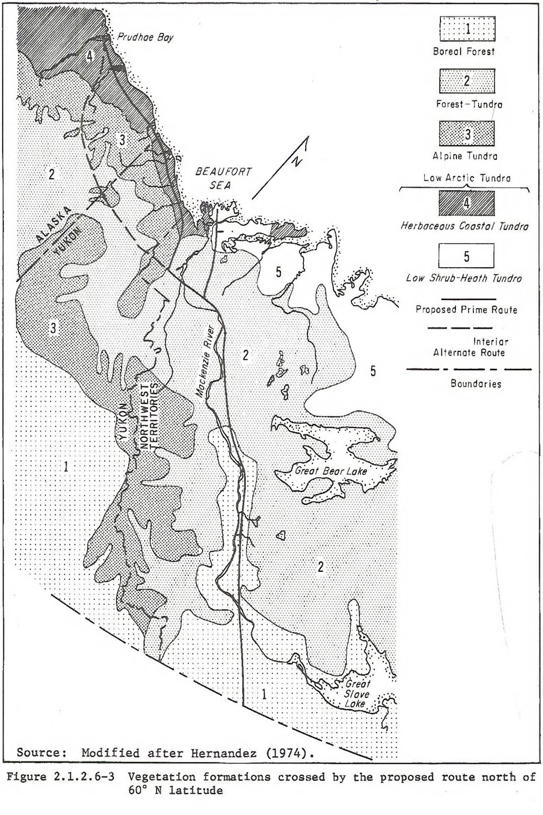
Tundra Formation

Herbaceous Coastal Tundra--Fronting the Beaufort Sea, the coastal plain and the low foothills (Figure 2.1.2.6-2; 2.1.2.6-3) which form its southern boundary have an essentially continuous cover of vegetation in which herbaceous species of the grass lifeform predominate. Permafrost more than 1000 feet deep, shallow seasonal thaw of only a few inches, massive ground ice, including ice wedges and their surface expression as polygonally patterned ground, are characteristic features. On the coastal plain, drainage is impeded both by the impervious frozen ground and the flatness of the terrain.



Base: G.S.C. Map 1254A (modified)

Figure 2.1.2.6-2 Selected physiographic provinces and subprovinces north of 60° N latitude



Source: Modified after Hernandez (1974).

Figure 2.1.2.6-3 Vegetation formations crossed by the proposed route north of 60° N latitude

Habitat differentiation by variations in topography is relatively minor and this, coupled with a very limited number of vascular plant species, results in highly repetitive plant communities of only a few types. The general aspect is one of wet meadows in which sedges are much more abundant than grasses. Mosses are important ground cover and peat-formers in nearly all plant communities.

The proposed route would originate in Alaska where the alignment crosses the broad coastal plain to the low foothills; it then passes eastward into Canada on elevated terrain. It would generally cross streams at right angles, above the points where they reach the coastal plain and form wide, braided channels on the low, flat terrain. In the Yukon, the Herbaceous Coastal Tundra occupies a much narrower area than in Alaska, being confined by the nearness of the British and Richardson Mountains to the sea (Figure 2.1.2.6-2). The route would cross 143 miles (Table 2.1.2.6-1) of Herbaceous Coastal Tundra communities.

On the coastal plain the numerous ponds and lakes exhibit zones of vegetation, related to water depth and drainage and soil aeration gradients, which are successional sequences. Through peat accumulation in which peat mosses (*Sphagnum* spp.) play an important role, the successive communities shift in on the water bodies which ultimately become peat filled. A common sequence includes pendent grass (*Arctophila fulva*) in deeper water, often mixed with mare's tail (*Hippuris vulgaris*) and *Ranunculus pallasii*, followed in shallower water by successive communities of cottongrass (*Eriophorum angustifolium* or *E. scheuchzeri*) *Carex aquatilis* the grass *Dupontia fischeri*, and several other sedges (*Carex chordorrhiza*; *C. rariflora*; *C. rotundata*; and *C. membranacea*). As peat mounds are built up and the sites become drier they are invaded by a number of species including woody species such as the prostrate willows (*Salix pulchra*; *S. phlebophylla*; *S. rotundifolia*; and *S. reticulata*), lingonberry (*Vaccinium vitis-idaea* subsp. *minus*), and dwarf birch (*Betula nana* subsp. *exilis*).

The foregoing species of dwarf shrubs become more prominent under the improved drainage of the foothills where, however, the dominant vegetation consists of cottongrass tussock communities. Rounded tussocks 10-18 inches in height are formed by the sedge, *Eriophorum vaginatum* subsp. *spissum*. Associated are numerous species of mosses and lichens, cloudberry (*Rubus chamaemorus*), several species of grasses and such heaths as lingonberry, crowberry (*Empetrum nigrum* subsp. *hermaphroditum*), Labrador tea (*Ledum palustre* subsp. *decumbens*) and bearberry (*Arctostaphylos rubra*). Within the tussock community which covers hundreds of square miles, wherever lakes and associated swamps occur, the sedge and grass communities that dominate the coastal plain also occur.

Along streams crossing both the foothills and the coastal plain, communities of tall shrubs 5-6 feet in height develop on banks and low alluvial terraces. The feltleaf willow (*Salix alaxensis*) is the most important species but others include *Salix arbusculoides* and *S. glauca* subsp. *desertorum*, and alder (*Alnus crispa*). Perennial herbs form pioneer communities on stream-deposited silts and also occur within the shrub communities which succeed them. These species include fireweed (*Epilobium latifolium*), wormwood (*Artemisia tilessii*; *A. alaskana*; and *A. arctica*) and several legumes (*Astragalus alpinus*; *Lupinus arcticus*; and *Oxytropis* spp.). Tussock communities cover up to 80 percent of the foothills.

Table 2.1.2.6-1 Estimated mileage of proposed pipeline right-of-way crossing major plant communities

		Vegetation									
		TUNDRA						Forest-Tundra		Boreal Forest	
	Segment Length	Herbaceous Coastal		Low Shrub-Heath		Alpine					
	Miles	Miles	%	Miles	%	Miles	%	Miles	%	Miles	%
Prudhoe Bay Supply Line to Travaillant Lake	297	145	49	-		-		152	51	-	
Richards Island Supply Line to Travaillant Lake	143	-		73	51	-		70	49	-	
Parsons Lake Lateral	15	-		15	100	-		-		-	
Main Line-Travaillant Lake to 60° N Latitude	695	-		-		-		192	28	503	72
Main Line-60° N Latitude to Caroline Junction	610	-		-		-		-		535	88
Monchy Delivery Line	394	-		-		-		-		—	
Kingsgate Delivery Line	281	-		-		-		-		-	
Canadian Total (System)	2,435	145		88		-		414		1,038	

Table 2.1.2.6-1 (Continued)

		Vegetation									
		PARKLAND				Grassland		Subalpine Forest		Interior Wet Belt Forest	
	Segment Length	Aspen		Ponderosa Pine							
	Miles	Miles	%	Miles	%	Miles	%	Miles	%	Miles	%
Prudhoe Bay Supply Line to Travaillant Lake	297	–		–		–		–		–	
Richards Island Supply Line to Travaillant Lake	143	–		–		–		–		–	
Parsons Lake Lateral	15	–		–		–		–		–	
Main Line-Travaillant Lake to 60° N Latitude	695	–		–		–		–		–	
Main Line-60° N Latitude to Caroline Junction	610	75	12	–		–		–		–	
Monchy Delivery Line	394	60	15	–		334	85	–		–	
Kingsgate Delivery Line	281	86	31	20	7	65	23	70	25	40	14
Canadian Total (System)	2,435	221		20		399		70		40	

Low Shrub-Heath Tundra--Eastward from the Herbaceous Coastal Tundra in parts of the northern Peel Plateau between the Mackenzie Delta and the Richardson Mountains, but principally east of the Delta north of Inuvik, Low Shrub-Heath communities previously mentioned increase in importance and occupy 75-90 percent of the land (Figures 2.1.2.6-2, 2.1.2.6-3) (Tables 2.1.2.6-2; 2.1.2.6-3). Tussock and sedge meadow communities occur on low wet sites and tall shrub riparian communities along streams as previously described. Distribution of these communities in several areas is given in Table 2.1.2.6-3.

The low shrubs of these communities occur on hilltops and slopes and reach a height of about 2 feet on the latter terrain and only about half this height on the more exposed sites. The dominant species, in variable mixtures, include dwarf birch, willows (Salix glauca subsp. acutifolia and S. pulchra), crowberry, Labrador tea, lingonberry, bearberry, and alpine blueberry (Vaccinium uliginosum subsp. alpinum). The low shrub-heath tundra would be crossed by 88 miles of right-of-way (Table 2.1.2.6-1).

Alpine Tundra--The proposed route would not cross mountains at altitudes bringing it into contact with Alpine Tundra. See discussion of alpine vegetation in Section 8.1.2.1 - Interior Route.

Forest-Tundra Formation

Lying between the Tundra to the north and the Boreal Forest, which reaches its northern limit north of Norman Wells, and below the Alpine Tundra of the higher mountains and plateaus, this formation (Figure 2.1.2.6-3) includes a great diversity of vegetation types (Tables 2.1.2.6-3; 2.1.2.6-4). Tree species from the Boreal Forest are intermixed with elements from both the Herbaceous Coastal Tundra and the Low Shrub-Heath Tundra. White spruce (Picea glauca), which reaches its northern limit near 69° N latitude, other conifers, and hardwood species contribute to the complex display of vegetation. Successional stages are abundant, especially those following fire which is an important ecological factor in this formation. The formation will be crossed by 414 miles of the proposed route.

Hernandez (1974) describes nine groups of communities along the proposed route in this zone, as follows:

Bogs--Acid peat deposits on wetlands of glacial lake basins and deltaic plains may lack trees or have scattered black spruce (Picea mariana). The vegetation is principally of sedges (Carex aquatilis and Eleocharis spp.), low heaths, such as Andromeda polifolia and Chamaedaphne calyculata, and peat moss (Sphagnum spp.).

Fens--Fens are wetland communities of thermokarst lakes and ponds, glacial lake basins, deltaic plains and fossil floodplains. They are mineral-rich as compared with bogs and the vegetation shares many of the same species of mosses, sedges and heaths mentioned above plus such herbs as buckbean (Menyanthes trifoliata), sweet gale (Myrica gale) and willows (Salix arbusculoides). Scattered black spruce and tamarack (Larix laricina) may be present. Between the Mackenzie Delta and Norman Wells 2.8 percent of the area is occupied by fens (Table 2.1.2.6-4). These are successional stages on

Table 2.1.2.6-2 Distribution of plant communities in the Low Shrub-Heath Tundra, Richards Island-Tuktoyaktuk region, N.W.T.

	Site							
	Eskimo Lakes		Caribou Hills		Tununuk Point		Tuktoyaktuk	
	Areas Covered by Community (%)							
Community Type	1	2 1/	1	2 1/	1	2 1/	1	2 1/
Low Shrub-Heath	48.3	54.7	74.5	82.8	29.8	37.2	34.8	51.0
Birch-Alder-Heath	26.2	29.7	3.6	4.0	13.6	17.0	3.6	5.3
Raised Centre Polygon	3.7	4.2	4.5	5.0	15.0	18.7	13.0	19.0
Total of Above 2/	78.2	88.6	82.6	92.0	58.4	73.0	51.4	75.5
Cottongrass Tussock	5.8	6.6	0.4	0.4	10.1	12.6	9.9	14.5
Wet Sedge Meadow and Lake Edge	0.4	0.5	0.6	0.7	7.2	9.0	4.1	6.0
Tall Shrub (Riparian)	2.6	3.0	2.7	3.0	0.2	0.3	0.1	0.1
Gravel and Beach Deposits	1.3	1.5	3.6	4.0	4.2	5.2	2.8	4.1
Water (Lakes)	11.6	-	9.5	-	20.0	-	31.9	-

Hernandez (1974)

1/ Percent of total land area covered by community type (i.e. lakes excluded).
2/ Complex of low shrub-heath types.

Table 2.1.2.6-3 Distribution of plant communities (percent) in the northern Yukon interior and coastal mountains 1/

	PHYSIOGRAPHIC REGION					
	INTERIOR				COASTAL MOUNTAIN	
Community Type	Peel Plateau	Richardson Mountains	Porcupine Plateau	Old Crow Range	British Mountains	Arctic Plateau
Forest-Tundra						
Mature forest-tundra	5	12	53	12	-	-
Hardwoods and mixed woods	2	-	10	-	-	-
Tall shrubs	6	4	3	-	-	-
Alpine and Low Arctic Tundra						
Low shrub-heath	17	30	2	25	23	8
Cottongrass tussock	44	3	7	15	14	21
Wet sedge meadow	6	2	-	-	-	-
Dry meadow	-	-	-	-	26	28
Other 2/	-	16	-	9	-	-

Hernadez, 1974

1/ Adapted from Hettinger and others (1973). Data did not total 100 percent in original.

2/ Includes rock with crustose and foliose lichens in Richardson Mountains (10%) and Old Crow Range (9%) and seasonal grass and herb steppe for Richardson Mountains (6%).

Table 2.1.2.6-4 Distribution of plant community types in the Forest-Tundra between Norman Wells and Travaillant Lake along the Mackenzie Valley

	COMMUNITY TYPE										
	Open Water			Wetlands	Riparian Succession			Fire Succession			
Area	Mackenzie River	Other	Exposed Rock	Fens	Pioneer Riparian	Steep Slope	Mature Riparian	Recent Burns	Hard-woods	Mixed-woods	Mature Forest Tundra
Acres	235,000	326,000	14,200	82,200	23,300	75,600	20,400	508,000	2,200	148,000	1,500,000
Percent	7.9	11.0	0.48	2.8	0.78	2.5	0.69	17.1	0.075	5.0	51.7

Source: Hernandez (1974).

floodplains subject to annual flooding. Pioneer species of sedges (*Carex aquatilis*) and horsetails (*Equisetum fluviatile*) are followed by a long-enduring tall-shrub stage of willows (*Salix alaxensis* and *S. interior*) and alders (*Alnus crispa* and *A. incana*) and often including balsam poplar (*Populus balsamifera*).

Steep Slope Riparian Communities--Along the steep riverbanks of deeply incised rivers communities of white spruce, poplars and willows occur much as in mature riparian communities (below) except the trees are smaller and occur at lower densities.

Mature Riparian Communities--These include the most productive forests in the North and consist of white spruce reaching heights to 80 feet with an understory of tall shrubs and ground cover of moss (*Hylocomium splendens*). The Mackenzie Delta south of treeline has about 1.75 million acres covered about half with water and half with these mature communities and their earlier successional stages. South of the delta in the northern Mackenzie Valley they cover only 0.7 percent of the land (Table 2.1.2.6-4).

Mature Forest-Tundra Communities--These include all sites with vegetation including spruce, usually black spruce, over 10 feet tall and a canopy density of 10 percent, as the dominant tree. The understory consists of heath, willow and alder shrubs and ground cover of mosses and lichens. These communities cover 52 percent of the northern Mackenzie Valley (Table 2.1.2.6-4).

Pioneer Grass-Herb-Shrub Communities--These communities occur on areas burned within the past 10 years. Burns are frequent in the Forest-Tundra excepting the Mackenzie Delta and other wet riparian sites. In the northern Mackenzie Valley (Table 2.1.2.6-4) 17 percent of the area was found to have burned within a decade. Numerous species of grasses and other herbs, such as fireweed, quickly seed in and regeneration of shrubs and other perennials may occur within one year if burning was not so severe as to destroy underground vegetative organs.

Mixedwood Communities--Here are included mixtures of conifers and deciduous hardwood species which are successional stages on upland areas burned 15-50 years ago. In the Mackenzie Valley and Peel and Porcupine Plateaus the vegetation consists of forests of white spruce-white birch-alder on well drained ridges and sloping uplands (Table 2.1.2.6-3). Undercover includes sparsely distributed herbs and dwarf shrubs and groundcover of moss (*Hylocomium splendens*). In the northern Mackenzie Valley a different assemblage includes black spruce-white spruce-white birch-aspen forests with a well-developed shrub layer of alder, Labrador tea and Bebb's willow (*Salix bebbiana*) and ground cover of moss and lichens (*Cladonia mitis*).

Hardwood Communities--White birch (*Betula papyrifera*) is the dominant species and forms pure stands on exposed ridges and slopes. These communities are very limited in their distribution and, like the mixedwood communities, are successional stages following fire. Hernandez (1974) cites data indicating fire in these stands about every 70 years.

Boreal Forest Formation

The main body of the transcontinental Boreal Forest that lies east of the Rocky Mountains reaches the latitude of Great Slave Lake in the Northwest Territories and attenuates in its distribution northward along the Mackenzie Valley. These highly productive forests reflect the ameliorating effect of the Mackenzie River on the regional environment, an effect that is maintained in some degree to the northern limit of spruce in the Forest-Tundra. The northern limit of "true" Boreal Forest is reached near Norman Wells (Figure 2.1.2.6-3). This is the Upper Mackenzie Section of the Boreal Forest Region of Rowe (1972). An estimated 503 miles of the proposed route would traverse Boreal Forest communities in the Northwest Territories to the Alberta border at 60° N latitude.

Community types previously described for the Forest-Tundra continue southward into the Boreal Forest with variations in areas, species diversity and other properties including greater productivity, as reflected by greater tree size. The distribution of Forest-Tundra community types given in Table 2.1.2.6-4 may be compared with that of the proposed route from Norman Wells to the Alberta border (Table 2.1.2.6-5).

Black spruce communities, with sphagnum moss ground cover on wetter terrain and lichen ground cover on upland sites, predominate along the Mackenzie River in the Forest-Tundra. Southward from Norman Wells these communities diminish relatively as the mature Boreal Forest types become more prominent within the Boreal Forest. White spruce, jack pine (*Pinus banksiana*) and poplar characterize these forests. White spruce and balsam poplar (*Populus balsamifera*) occupy the alluvial deposits along the rivers. Well-drained ridges have forests with well-developed shrub layers of alder, Labrador tea and Bebb's willow (*Salix bebbiana*) with ground cover of moss and lichens (*Cladonia mitis*). There is a marked increase in these forests south of Fort Simpson.

From about 40 miles north to 100 miles south of Fort Simpson there is also a large increase in the number and total acreages of fens. Vegetation of these fens consists of communities of dwarf birch, sedges and tamarack (*Larix laricina*). Peat bogs and peat plateaus are also common.

From about the latitude of the south shore of Great Slave Lake to the Alberta border the spruce-jack pine communities decrease in relative importance and there is a concomitant increase in spruce-aspen (*Populus tremuloides*) types of vegetation. Well-drained uplands have a cover of black spruce, aspen, white birch and lodgepole pine (*Pinus contorta* subsp. *latifolia*).

Alberta, Saskatchewan and British Columbia

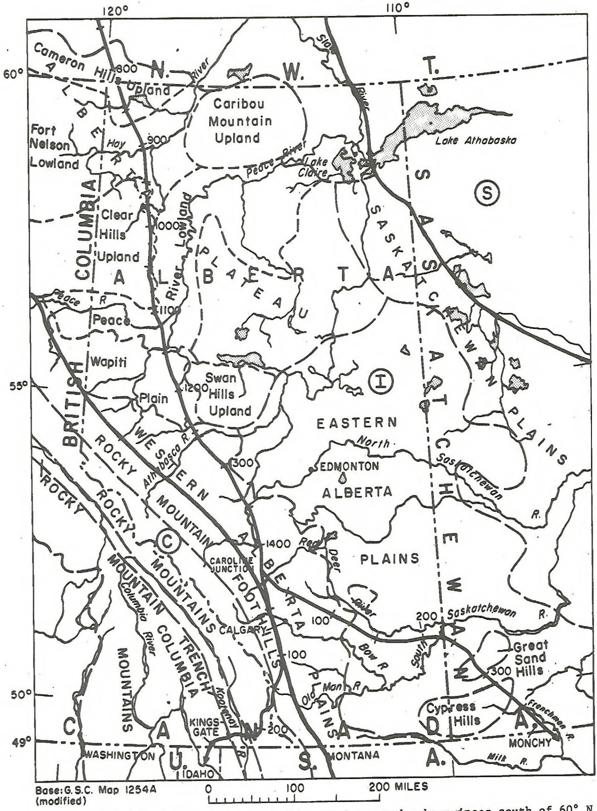
Boreal Forest Formation

Conifers, hardwoods and mixedwoods dominate 88 percent, or 535 miles, of the proposed pipeline route between N.W.T.-Alberta border and Caroline Junction (Figures 2.1.2.6-1, 2.1.2.6-4 and 2.1.2.6-5; Table 2.1.2.6-1). Vegetation description of this and other formations in the Provinces is based primarily upon CAGPL (1974e), Fremlin (1974), Government of Alberta (1969), Richards and Fung (1969) and Rowe (1972).

Table 2.1.2.6-5 Distribution of plant community types in the Forest-Tundra between the Alberta-N.W.T. boundary and Norman Wells along the proposed route

Community Type	South of Fort Simpson Acres	South of Fort Simpson Percent	North of Fort Simpson Acres	North of Fort Simpson Percent
Open Water				
Mackenzie River	29,400	1.0	241,000	9.7
Other	64,300	2.2	135,000	5.4
Exposed Rock	0	0	34,700	1.4
Wetlands				
Bogs	1,600	0.056	1,400	0.058
Fens	282,000	9.7	32,300	1.3
Riparian Succession				
Pioneer Riparian	0	0	17,400	0.70
Steep Slope	5,200	0.18	85,600	3.5
Mature Riparian	10,600	0.37	46,600	1.9
Fire Succession				
Recent Burns	21,100	0.73	54,600	2.2
Hardwoods	43,300	1.5	43,900	1.8
Mixedwoods	603,000	20.9	533,000	21.5
Mature Boreal Forest	1,833,000	63.3	1,238,000	50.0
TOTAL	2,893,000		2,476,000	

Source: Hernandez (1974).



Base: G.S.C. Map 1254A (modified)

Figure 2.1.2.6-4 Selected physiographic provinces and subprovinces south of 60° N latitude

Passing into Alberta within the Hay River Section (Rowe, 1972) of the Boreal Forest, jack pine is abundant to the east and lodgepole pine has a limited distribution to the west. In northwestern Alberta aspen forests are the most important forest types, south-facing slopes having pure stands and the north-facing slopes having aspen and white birch (CAGPL, 1974e). Muskeg of sphagnum mosses and black spruce covers approximately 70 percent of the region. White spruce of excellent merchantable quality occurs on the floodplains of the Liard and lower Peace Rivers (Rowe, 1972). Sandy terraces and rock till above the Liard have a cover of poplar, birch and spruce with scattered lodgepole pine. In similar areas with the same deciduous species, along the Slave River, jack pine is the usual coniferous species.

The Hay River Section, which extends about to the Chinchaga River, has a colder and drier climate than the Mixedwood Section (Rowe, 1972) of which it is a northern extension. The mixedwood forests are of better quality and are more diverse, including white birch, Alaska birch (Betula papyrifera var. humilis), balsam fir (Abies balsamea) and jack pine (CAGPL, 1974e). Aspen, balsam poplar and white birch in combination with white spruce and balsam fir, especially in old stands, are characteristic of well-drained uplands (Rowe, 1972). As a result of fire, aspen has the largest areal coverage in this section. Black spruce and tamarack occur in the muskeg of lowland areas. Between the Chinchaga River and Grimshaw, alpine fir (Abies lasiocarpa) is mixed with the upland forest dominants. In this area forests are mixed with grazing and agricultural lands (CAGPL, 1974e). the latter occupying 75-85 percent of the land around Valleyview.

In the Peace River region the proposed route crosses extensive agricultural lands which were originally grassland and outliers of aspen parkland, the Aspen Grove Section of Rowe (see Parkland Formation). Although the grasslands are largely gone, in their original state they consisted of a wheat grass (Agropyron trachycaulum)-needlegrass (Stipa spartea var. curtiseta)-sedge (Carex spp.) community (CAGPL, 1974e).

Crossing the Alberta Plain (Figure 2.1.2.6-4), north of the Athabasca River, the proposed route passes from the Mixedwoods to Rowe's Lower Foothills Section. The latter is a transition between the Boreal Forest and the Subalpine Forests in the foothills of the Rocky Mountains (Figure 2.1.2.6-1). Most of the characteristic Boreal Forest hardwoods and conifers previously mentioned occur in this section with lodgepole pine. Lodgepole pine, aspen and balsam poplar are dominant following fire, and white spruce is an important constituent of older stands. Balsam fir and alpine fir are common locally although of small importance overall (Rowe, 1972). The proposed Main Line would end near the southeastern limit of this section at Caroline Junction.

Parkland Formation

Aspen--Bordering the original grasslands of the Peace River area of Alberta, southern Alberta, and Saskatchewan (Figures 2.1.2.6-1 and 2.1.2.6-5) closed forests of aspen, or park-like forests of aspen mixed with grassland, formed characteristic communities. Much of the area formerly occupied by Aspen Parkland is now under cultivation or devoted to grazing.

This type of parkland would be crossed by the proposed Main Line in the Peace River area, as previously mentioned. The Kingsgate Delivery Line and the Monchy Delivery Line would traverse it for about 86 and 60 miles respectively.

Ponderosa Pine--Open forests of Ponderosa pine (Pinus ponderosa) and occasional interior Douglas fir (Pseudotsuga menziesii) are intermixed with bunch-grass prairie in part of the upper Columbia River valley of southeastern British Columbia. For approximately 20 miles the Kingsgate Delivery Line would cross parkland. At higher elevations Douglas fir forests alternate with areas of aspen and lodgepole pine. These vegetation types are part of the Montane Forest of Rowe (1972).

Bur Oak--In southwestern Manitoba this parkland has bur oak (Quercus macrocarpa) as its principal hardwood species. It is not crossed by the proposed pipeline but is by a possible route alternative treated in Section 8.1.2.5.

Grassland Formation

Approximately 334 miles of the Monchy Delivery Line and 65 miles of the Kingsgate Delivery Line would cross agricultural lands of former low-grass and mid-grass prairie grassland (Figure 2.1.2.6-5; Table 2.1.2.6-1).

Subalpine Forest Formation

The proposed Kingsgate Delivery Line (Figures 2.1.2.6-1, 2.1.2.6-4 and 2.1.2.6-5) would extend southward from Caroline Junction, in the Lower Foothills Section of the Boreal Forest, to a crossing of the southwestern extension of the Aspen Parkland, as previously described, and into the Upper Foothills Section of the Boreal Forest (Rowe, 1972). The latter lies in a narrow belt along the front range of the Rocky Mountains, reaches an altitude of 6,000 feet above sea level, and is forested to the summit, predominantly by lodgepole pine and white spruce. Alpine fir, black spruce and tamarack are present in scattered distribution and poplars and birch are only sparsely represented.

The proposed route will then cross the East Slope Rockies and Interior Sections of the Subalpine Forest. This forest differs from the Upper Foothills Section of the Boreal Forest by the presence of Engelmann spruce (Picea engelmanni) and its hybrids with white spruce. At higher altitudes alpine fir is abundant. Jack pine and lodgepole pine are present, the latter replacing spruce over large areas following fire. Poplars, birch and black spruce are of limited importance here, compared to the Boreal Forest. About 70 miles of the Kingsgate Delivery Line would cross Subalpine Forest, mostly on the east slope of the Rocky Mountains in Alberta.

Interior Wet Belt Forest Formation

On both sides of the Kootenay Valley and on slopes to Kingsgate, this formation, the Southern Columbia Section of the Columbia Forest Region (Rowe, 1972) occurs at altitudes of 2,500-4,000 feet (Figure

2.1.2.6-1). The climate is more moist than to the west and south where there is a transition to Montane Forest or grassland and the valley forests are similar in composition to the Coast Forest of the Pacific coast. The dominant species of mature forest are western hemlock (Tsuga heterophylla) and western red cedar (Thuja plicata) and interior Douglas fir is generally associated. The present forests near the proposed route are lodgepole pine and western larch (Larix occidentalis) on dry sites following fire. On recent alluvial soils black cottonwood (Populus trichocarpa) occurs with western red cedar and white or Engelmann spruce (Rowe, 1972). About 40 miles of the Kingsgate Delivery Line will lie within this formation.

Human Influences on Existing Vegetation

General Nature of Influence

Throughout the 2,435 miles of proposed route in Canada evidence of human influences are found in the vegetation. Expectedly, the frequency of occurrence of areas of disturbed vegetation, as well as the size of area and the intensity of the effects, are related directly to population centers and availability of transportation. The proposed route extends from heavily industrialized urban centers and intensive agricultural areas of the southern and central prairie Provinces to areas in the Yukon and Northwest Territories that are essentially unpopulated or have only small, scattered and often primitive villages, or very modern ones, as Inuvik. All-weather roads, which form a dense network in the south, east of the Rocky Mountains and as far north as the Athabasca River, and occur at lesser frequencies in the Peace River agricultural region, are represented by a single highway along the pipeline corridor to the Northwest Territories.

The latter, the Mackenzie Highway, is completed as an all-weather road from Grimshaw, Alberta to the Willowlake River in the Northwest Territories, and is scheduled for completion as far as Wrigley by 1978. When fully completed it will terminate at the Dempster Highway near Inuvik. The Dempster Highway is a partially completed all-weather road 450 miles in length from Dawson, Yukon Territory to Inuvik which may be completed by 1978.

There are no railways along the proposed route and only the Great Slave Railway to Hay River and Pine Point on Great Slave Lake extends into the Northwest Territories. From Great Slave Lake the Mackenzie River has long been the principal artery of transportation to the arctic coast. Air travel by bush plane has for many years made all parts of the Canadian North readily accessible and commercial flight services are available to most settlements.

Native peoples, before the coming of large numbers of southern man and his machines, had small influence on the natural vegetation. Food gathering, forest fires and clearing of timber induced only local vegetation change about the settlements. These settlements are concentrated along the Mackenzie River, the arrival of man from industrial society was largely by the same river route and human influences on vegetation were accordingly greatest along that river system.

The Mackenzie River is a natural transportation corridor with a long history of uses which have taken a light toll of the vast renewable vegetation resource. These uses are the same as those of people everywhere. Land is cleared for construction sites of settlements, airstrips, roads, and communication lines, and for access to gravel borrow areas to obtain construction materials. Trees are cut for construction logs, saw lumber, and fuel or otherwise removed for access along winter trails and seismic lines. Fire is a common feature accompanying all human activities and vast acreages of vegetation are burned every year. Many of these fires, however, result from natural causes such as lightning strikes. Fire is an important ecological factor influencing the natural character of vegetation in the Forest-Tundra, Boreal Forest and coniferous forests of the Rocky Mountains.

The aerial view of the Mackenzie corridor displays the visual scars left by all types of vegetation disturbances. Long distances can be flown with little or no evidence of disruption until the clearings, local roads and trails mark the approach to one of the infrequent settlements. Roads completed and those under construction exhibit their familiar patterns of linear intrusion through plant communities and the scars of frequent borrow pits which have furnished gravel for their construction.

The frequency of the scars of human activity is sufficiently great to have long since destroyed the wilderness quality of vegetation along the immediate, developed transportation corridor. Outside the corridor burn areas which may or may not be of human origin, and seismic trails left by geophysical exploration parties, are the principal disruptions to plant communities. Where seismic trails are lacking, wilderness characteristics prevail.

Prudhoe Bay Supply Line

Vegetation change along the proposed supply line has been minor although many kinds of exploratory activities entailing use of off-road vehicles have left their marks. Whaling brought early activity to the coastal area but with negligible known effects to vegetation. There are no roads or villages in the tundra vegetation of the arctic coast. Construction of the Distant Early Warning (DEW Line) radar stations in 1955 brought major but local construction to the region. As with settlements, destruction of vegetation was mainly confined to the environs of the sites, and to airstrips and short haul roads in the vicinity. Fire is not a significant factor in the herbaceous plant communities.

Skirting the Mackenzie Delta the proposed route would pass Fort McPherson with a population of 761 and Arctic Red River with a population of 122. Timber is harvested in the Mature Riparian Spruce and Mixedwood forests for local use. Between these settlements the Dempster Highway roughly parallels the proposed right-of-way and at Arctic Red River crosses the Mackenzie River and turns north toward Inuvik. Forest-Tundra communities of upland sites are susceptible to fire.

Richards Island Supply Line

The Mackenzie Delta vegetation has been marked extensively by off-road vehicular traffic, seismic lines, winter trails and oil and gas exploratory drilling sites. The hamlet Aklavik with a population of 761 lies within the Herbaceous Coastal Tundra. Tuktoyaktuk on the north coast, in Low Shrub-Heath vegetation, has a population of 585.

Inuvik, a modern town of 4,150, has a full array of transportation, communication and community services. All of the areas about the communities exhibit the same types of influences on vegetation, the magnitude varying only with community and population sizes. Fire, of relatively minor concern in the other vegetation types, is always a warm season threat in the Forest-Tundra. Around Inuvik burn areas and fire breaks are very evident. The Dempster Highway terminates at Inuvik as will the connecting Mackenzie Highway when constructed.

Main Line--Travaillant Lake to N.W.T.--Alberta Border

Along this 695-mile segment there are 13 communities, seven of which lie along and in proximity to the Mackenzie River routes of both the Mackenzie Highway, as constructed or proposed, and the proposed pipeline. Fort Good Hope (pop. 421) is within the Forest-Tundra. Norman Wells (pop. 354), Fort Norman (pop. 232), Wrigley (pop. 213), Fort Simpson (pop. 851), and Jean Marie River (pop. 47) all lie within the Boreal Forest along the Mackenzie River to the proposed pipeline crossing southeast of Fort Simpson. The remaining six communities, although more remote from the proposed route, lie within the Mackenzie River system and the Boreal Forest and have had proportionate effects on the vegetation.

All previous general and specific comments regarding the Mackenzie River Valley and the Forest-Tundra are applicable to this segment. Winter trails have been widely used for many years and winter roads were constructed along the east side of the Mackenzie in the mid 1940's and 1960's. Timber cutting has been extensive in both riparian and upland spruce forests in the Boreal Forest and evidence of burns and seismic trails is abundant.

Exploration for oil began at Norman Wells in 1919 and oil was discovered in 1920. Beginning in 1942, there was extensive geophysical exploration and wildcat drilling up and down the river from Norman Wells. As part of the Norman Wells development, the Canol Pipeline and road 660 miles in length were constructed to Whitehorse in the Yukon. Much of this road is abandoned and natural revegetation is well along. Exploration for oil and gas was renewed in the 1950's and was extensive along the Mackenzie River by the mid-1960's. The Peel Plateau has also been intensively explored for oil and gas.

Main Line--N.W.T.-Alberta Border to Caroline Junction

Within the Province of Alberta, human influences on natural vegetation in the regions traversed by 610 miles of the proposed route have been extensive and intensive over long periods of time. Much of the natural vegetation has been destroyed or subjected to major modification through lumbering; agriculture; grazing; reforestation; oil and gas production, refining, and transportation; coal mining; and a host of other activities attendant to providing energy, materials and services to large populations of people.

The most productive forest lands along the route north of the latitude of Lesser Slave Lake were in the Hay River and Peace River regions. Coniferous, mixedwood and deciduous forests have been harvested for many years. In these areas there are large areas of potentially productive forest land intermixed with non-forested muskeg with only scattered trees. South of Lesser Slave Lake timber cutting effects on the forests have been pronounced. Conifers were and still are important timber trees to the south of Lesser Slave Lake and west of Athabasca as well as along the Rocky Mountain foothills and mountains. Mixedwoods and deciduous forest also have had heavy utilization for saw lumber and pulp wood all the way to Caroline.

Agriculture has long dominated the former grasslands and aspen parklands of the Peace River area where more than 50 percent of the land is under cultivation. South of the Athabasca River along the route to Caroline less than 50 percent of the land is under cultivation in an area of spruce-aspen vegetation and increases to more than 50 percent closer to the Aspen Parkland.

Kingsgate Delivery Line

The principal influences on vegetation have been lumbering, in the Subalpine Forest of Alberta and British Columbia and within the Ponderosa Parkland and Interior Wet Belt Forest of British Columbia, and agriculture in Alberta. The entire proposed route outside the Subalpine Forests is intensively cultivated in areas of former aspen parklands and grassland.

Monchy Delivery Line

The entire 394 miles lies within former grassland and aspen parklands, now largely under intensive cultivation or grazing in both Alberta and Saskatchewan.

Unique, Sensitive, and (or) Threatened Ecosystems or Communities

The plant component of ecosystems, the vegetation, would not be threatened by the proposed pipeline construction or operation at the scale of the plant formations or any of their major component communities. To be threatened a plant community would have to be one or few of a kind, and at a scale all or most of its area would be obliterated by the right-of-way, haul roads, campsites, compressor stations, or other facilities. It is possible, but improbable, that such vegetation units occur in such a vulnerable state in the Territories where vegetation generally exists in its natural state. In the more urbanized or agricultural areas of the provinces any additional imposition of disturbing influences could eradicate rare remnant vegetation, such as grassland communities, which have survived previous disturbances.

Vegetation types in the Boreal Forest and all other formations to the north are widespread and highly repetitive. The intrusion of a long, narrowly linear highway or pipeline into such areas would affect other ecosystem components and detract from esthetic quality of the landscape, but present no threat to vegetation. Exceptions which might occur would be small and unique populations of specialized habitats such as thermal springs, sand dunes, or perhaps certain small lakes. Whether any vegetation unique to such habitats occurs in the area of the proposed pipeline is not known.

Tundra communities are sensitive to disruption largely because of their slow rates of recovery. This is especially true of Herbaceous Coastal Tundra communities which in Canada are of limited extent along the proposed pipeline route. The cumulative effects of pipelines, possible off-shore oil and gas production, pipeline gathering fields or roads not now planned but which can be anticipated could threaten this restricted type of vegetation.

Threatened Species

No rare plant species are known which might be threatened by the construction or operation of the proposed pipeline or its ancillary facilities. While the possibility exists, it is improbable that the only extant representatives of a plant species population occur only on the right-of-way alignment or related areas that would be occupied by project components.

2.1.2.7 Wildlife

Fishery Resources

The following section describes the habitats and utilization of the fishery resources of the drainage basins along the proposed route (Figures 2.1.2.7-1, -2, and -3). The information presented was obtained primarily from the following sources: Environment Protection Board (1974a,b), and Paetz et al. (1970).

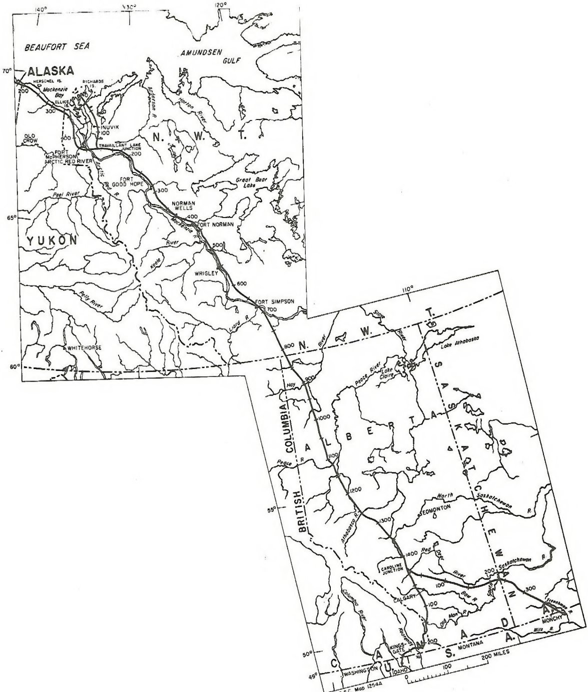
Beaufort Sea Drainage

The Beaufort Sea drainage (Figure 2.1.2.7-2) extends eastward from the Alaska-Yukon boundary at about Milepost 195 (Figure 2.1.2.7-1) through the Fish River system at about Milepost 340. This region lies in the continuous permafrost zone and has a mean annual air temperature ranging from -11° to -8° C. Soils in this region include silt or silt-covered gravels. The fresh waters in this region include mountain streams, foothill lakes, small tundra streams and numerous ponds and lakes. Foothill lakes are relatively deep and free of vegetation. Tundra lakes typically are shallow, contain profuse vegetation and the water is often stained brown or yellow. Few lakes support populations of fishes over the winter because the lakes either freeze to the bottom or develop lethally low dissolved oxygen levels.

Fifteen species of freshwater fish are known from this region (Table 2.1.2.7-1). Arctic char and Arctic grayling are the most widespread and abundant species present. Fish overwinter in streams having a sufficient source of groundwater to provide a continuous flow throughout the winter months. Both Arctic char and Arctic grayling overwinter in the Malcolm, Firth and Babbage Rivers systems. Whitefish and cisco found in this region probably overwinter in the Mackenzie River but move into many of the tributary streams to feed during the summer. Spring-fed streams are used also as spawning sites by Arctic char. Streams without ground water are utilized for feeding areas and provide spawning and nursery habitat for Arctic grayling. Most of the species spawn upstream from the proposed route.

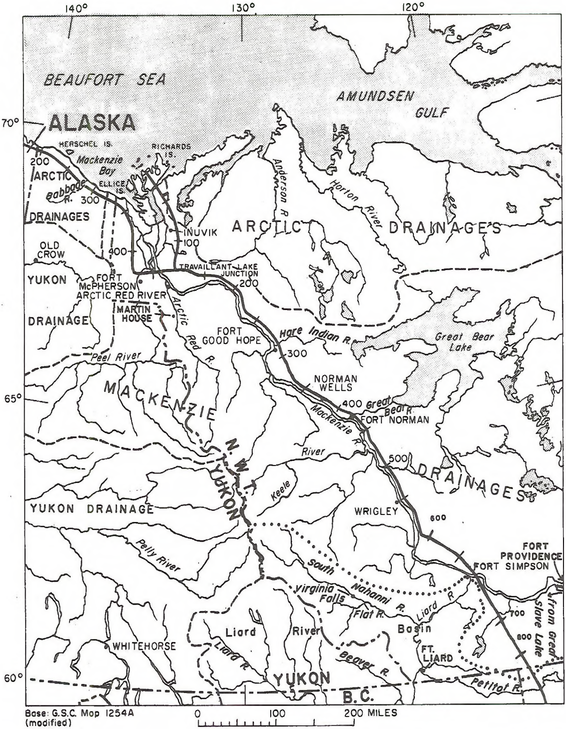
Arctic grayling and stream-dwelling Arctic char feed primarily on invertebrates. Grayling, especially, are insectivorous. Burbot eat fish and whitefish feed mostly on benthic organisms.

Human use of the fish resources is small. Two Eskimo families on Herschel Island took about 300 Arctic char and a like number of cisco during 1970-71. Efforts at commercial fishing in this region have failed.



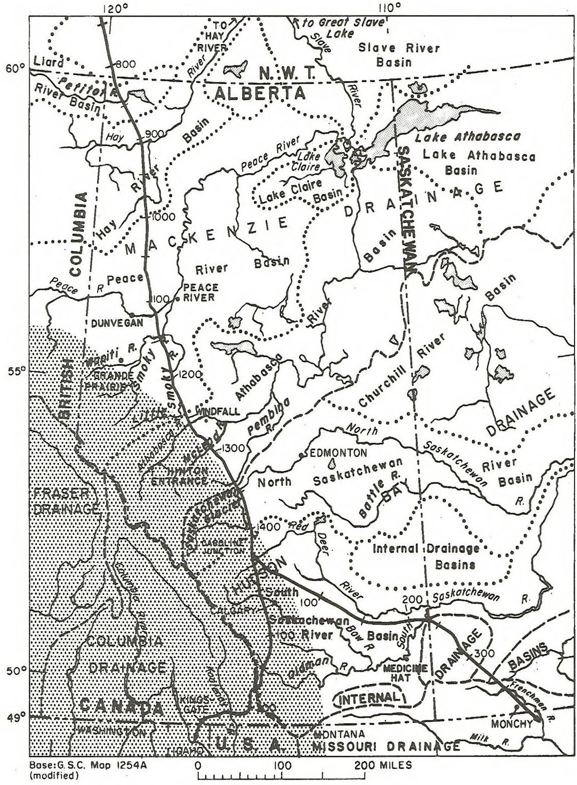
Base: G.S.C. Map 1254A (modified)

Figure 2.1.2.7-1 Principal rivers of the proposed route



Base: G.S.C. Map 1254A (modified)

Figure 2.1.2.7-2 Drainage basins and selected place names in the region of the proposed route north of 60° N latitude



Base: G.S.C. Map 1254A (modified)

Figure 2.1.2.7-3 Drainage basins and selected place names in the region of the proposed route south of 60° N latitude

Table 2.1.2.7-1 Fish species present in the Beaufort Sea (Arctic Ocean) drainage

Species	
Common Name	Scientific Name
Arctic cisco	*Coregonus atumalis*
Arctic grayling	*Thymallus arcticus*
Arctic char	*Salvelinus alpinus*
Lake trout	*Salvelinus namaycush*
Inconnu	*Stenodus leucichthys*
Humpback whitefish	*Coregonus pidschian*
Round whitefish	*Prosopium cylindraceum*
Broad whitefish	*Coregonus nasus*
Least cisco	*Coregonus sardinella*
Northern pike	*Esox lucius*
Burbot	*Lota lota*
Ninespine stickleback	*Pungitius pungitius*
Slimy sculpin	*Cottus cognatus*
Fourhorn sculpin	*Myoxocephalus quadricornis*
Pond smelt	*Hypomesus olidus*

Mackenzie River Drainage

The proposed route passes through the Mackenzie River drainage from about Milepost 340 on the Prudhoe Bay Supply line and Milepost 0 on Richards Island Supply Line to about Milepost 1350 on the Main Line (Figure 2.1.2.7-1). Water temperatures of the Mackenzie River system are generally warmer in the southern sections, and cool as the water flows northward. Dissolved solids generally increase as water flows from the headwaters to the mouth. Generally water in the drainage is clear with highest levels of dissolved solids in the winter. Suspended solids are highest during the warm open-water season.

Twelve major tributaries, most of which have drainages of over 1,000 square miles, flow directly into the Mackenzie River (Table 2.1.2.7-2). Major tributaries entering from the east downstream of the Liard River have softer water than those entering from the west. Major tributaries on the east side of the lower Mackenzie River flow throughout the winter. Six drainages on the east side of the Mackenzie Valley had higher numbers of mayflies, stoneflies and true flies than six western drainages. Invertebrate and fish production appears to be greater in tributary streams entering from the east side of the Mackenzie River.

At least 48 species of freshwater and anadromous fishes have been reported from the Mackenzie River system (Table 2.1.2.7-3). Thirty-four species have been found north of the 60° N latitude and 38 species between there and source of the river. Arctic grayling and northern pike appear to have the widest distribution. Arctic char, smelts, Arctic cisco, and least cisco are found primarily in the Mackenzie Delta area. Arctic char, cisco, and whitefish are abundant from Fort McPherson northward while northern pike are abundant throughout the system north of 60° N latitude. At least 15 species occur in the upriver area south of 60° N latitude.

Movements of fish in the Mackenzie River system are generally associated with spawning, feeding, and overwintering. The fall-spawning whitefish, inconnu and cisco probably migrate upriver and spawn in the mainstem of the Mackenzie River, and tributaries that include the Peel, Arctic Red, and Great Bear Rivers. The spring-spawning Arctic grayling, northern pike, walleye and longnose sucker make less extensive spawning movements. During the spring Arctic grayling move up river to smaller streams to spawn and feed. In the fall they move into spring-fed areas, downstream to larger and deeper streams, or to deep lakes to overwinter. Arctic grayling are known to overwinter in the Great Bear and Liard River systems. A list of known and suspected spawning and nursery areas is given in Table 2.1.2.7-4. Walleye, Arctic grayling, Arctic char and burbot use clear streams for spawning and nursery areas, whereas whitefish, cisco, longnose sucker, and northern pike use both clear and turbid waters as spawning sites and nursery areas.

About 62 percent of the Mackenzie River species are autumn spawners. Burbot spawn in late winter and rest during the spring.

Autumn spawners tend to spawn along the shores of lakes or in large rivers such as the Mackenzie, Peel, Arctic Red, and Great Bear. These are streams that do not freeze to the bottom and maintain sufficient flow and dissolved oxygen during the winter months to sustain the slowly developing eggs.

Table 2.1.2.7-2 Major tributaries of the Mackenzie River

River Name	East Side	West Side
Peel		X
Arctic Red		X
Liard		X
Trout		X
Keele		X
Redstone		X
Hare Indian	X	
Willowlake	X	
Loon	X	
Blackwater	X	
River Between Two Mountains	X	
Great Bear	X	

Table 2.1.2.7-3 Fish present in the Mackenzie River drainage and their distributions north and south of 60° N latitude

Species		Distribution	
Common Name	Scientific Name	North	South
Arctic lamprey	*Lampetra japonica*	X	
Arctic grayling	*Thymallus arcticus*	X	X
Arctic char	*Salvelinus alpinus*	X	
Brook trout	*Salvelinus fontinalis*		X
Dolly varden	*Salvelinus malma*	X	X
Lake trout	*Salvelinus namaycush*	X	X
Chum salmon	*Oncorhynchus keta*	X	
Kokanee	*Oncorhynchus nerka*		X
Humpback whitefish	*Coregonus pidschian*	X	
Broad whitefish	*Coregonus nasus*	X	
Arctic cisco	*Coregonus autumnalis*	X	
Least cisco	*Coregonus sardinella*	X	
Lake cisco	*Coregonus artedii*	X	X
Shortjaw cisco	*Coregonus zenithicus*		X
Lake whitefish	*Coregonus clupeaformis*		X
Brown trout	*Salmo trutta*		X
Cutthroat trout	*Salmo clarki*		X
Rainbow trout	*Salmo gairdneri*		X
Northern pike	*Esox lucius*	X	X
Rainbow smelt	*Osmerus mordax*	X	
Pond smelt	*Hypomesus olidus*	X	
Goldeye	*Hioden alosoides*	X	X
Flathead chub	*Hybopsis gracilis*	X	X
Lake chub	*Couesius plumbeus*	X	X
Spottail shiner	*Notropis hudsonius*	X	X

Table 2.1.2.7-3 (Continued)

Species		Distribution	
Common Name	Scientific Name	North	South
Emerald shiner	*Notropis antherinoides*	X	X
Longnose dace	*Rhinichthys cataractae*	X	X
Northern redbelly dace	*Phoxinus eos*	X	X
Finescale dace	*Phoxinus neogaeus*	X	X
Pearl dace	*Semotilus margarita*		X
Northern squawfish	*Ptychocheilus oregonensis*		X
Redside shiner	*Richardsonius balteatus*		X
Fathead minnow	*Pimephales promelas*		X
Largescale sucker	*Catostomus macrocheilus*		X
Longnose sucker	*Catostomus catostomus*	X	X
White sucker	*Catostomus commersoni*	X	X
Burbot	*Lota lota*	X	X
Trout-perch	*Percopsis omiscomavcus*	X	X
Ninespine stickleback	*Pungitius pungitius*	X	X
Brook stickleback	*Culaea inconstans*	X	X
Iowa darter	*Etheostoma exile*		X
Yellow perch	*Perca flavescens*		X
Walleye	*Stizostedion vitreum*	X	X
Slimy sculpin	*Cottus cognatus*	X	X
Spoonhead sculpin	*Cottus ricei*	X	X
Mountain whitefish	*Prosopium williamsoni*	X	X
Round whitefish	*Prosopium cylindraceum*	X	
Inconnu	*Stenodus leucichthys nelma*	X	
Peamouth	*Myiocheilus caurinus*		X

Table 2.1.2.7-4 Summary of spawning and nursery areas, Mackenzie River system

River Name	Arctic Graying	Arctic Char	Inconnu	Broad Whitefish	Humpback Whitefish	Round Whitefish	Least Cisco	Arctic Cisco	Northern Pike	Yellow Walleye	Burbot	Longnose Sucker	Lake Trout
Kakisa R.	S								S	S		S	
Trout R.	SN								sN	s		S	
Jean Marie Ck.	s			s	s				S	SN	N	SN	
Martin R.	SN			N	N				sN	sN	SN	sN	
(unnamed)	N												
Willowlake R.	N				N	N			s	sn	s	s	
(unnamed)	N												
R. Between Two Mts.	s												
Smith Ck.												n	
(unnamed)	N											n	
Hodgson Ck.	N												
Ochre R.	N					n					S	SN	
(unnamed)	N												
Blackwater R	N					N						n	
(unnamed)	N											n	
Saline R.	n											N	
(unnamed)	N												
(unnamed)	N												
Little Smith Ck.	n											n	
Big Smith Ck.	N								n				
(unnamed)	n												
(unnamed)	n												
Great Bear R.	sn					sn	n	sn	sn		sn	sN	N
Vermilion Ck	Sn			N	N	N	N	N		sN		sN	
Prohibition Ck.				N	N							s	
Heluva Ck.	n												
Francis Ck.	n												
Canyon Ck.	N												

S = Known Spawning area
s = Suspected spawning area
N = Known nursery area
n = Suspected nursery area

Table 2.1.2.7-4 (Continued)

River Name	Arctic Grayling	Arctic Char	Inconnu	Broad Whitefish	Humpback Whitefish	Round Whitefish	Least Cisco	Arctic Cisco	Northern Pike	Yellow Walleye	Burbot	Longnose Sucker	Lake Trout
Bosworth Ck.	n												
Oscar Ck.	sn		N	N	N				s	s		sN	
Elliot Ck.	n												
Hanna R. (U)	n											n	
Hanna R. (L)						n						sn	
Tsintu R.										SN		SN	
Hare Indian	SN					N						N	
Loon R.	n			N	N	n	N	N	n			sN	
Tieda R.	N									n			
(unnamed)	N												
(unnamed)	n												
(unnamed)	N												
(unnamed)	n												
Thunder R.	s												
(unnamed)	N												
(unnamed)	N												
Rengling R. (U)	SN		N	N	N				SN	sn	s	sN	
Rengling R. (L)	SN		N	sN	N				SN	sn	s	sN	
Tsintal Trein Ck.	N			N	N							s	
(unnamed)									N				
Frog Ck. (L)				sN	N		N	N	SN			sN	
Peel R.		sN	sN	sn	sn		sN	sN					
(unnamed)												n	
Rat R.		SN											
Willow R.	N	N											
(unnamed)	N												
Cache Ck.	N	S											
Fish R.	N	SN											
(unnamed)	N	SN		s					n				
Big Fish	N	SN										SN	

S = Known spawning area
s - Suspected spawning area
N = Known nursery area
n = Suspected nursery area

Spring spawners often utilize small streams that are unsuited to autumn spawners. The winter problems of ice and low oxygen content do not affect spring spawners although they often have to contend with fluctuating water levels.

Utilization of the fisheries resources appears to be greatest in the Mackenzie Delta and in lakes. Subsistence catches in the Mackenzie Valley were estimated to be about 700,000 pounds in 1972. The catches at individual locations are given in Table 2.1.2.7-5.

Commercial quotas for lake trout and whitefish in the Aklavik and Inuvik areas of the Mackenzie Delta were 10,000 and 50,000 pounds respectively in 1972. The commercial fishery has almost eliminated lake trout from the western part of Great Slave Lake.

Saskatchewan and Missouri River Drainages

In Alberta the Main Line south of about Milepost 1350 crosses watercourses draining into the Saskatchewan River which eventually empties into Hudson Bay. The major streams crossed are the North and South Saskatchewan Rivers. The most of Monchy Delivery Line (Figure 2.1.2.7-3) crosses the prairies where the drainage is dominated by a few large rivers--the Red Deer, Bow and South Saskatchewan. The Northern part of the Kingsgate Delivery Line crosses the headwaters of the South Saskatchewan River system.

These streams are frequently silty but productive. There are few tributaries and most of them are intermittent, flowing only during the spring melt. Streams that flow continuously are often sluggish, have high summer temperatures, and may either freeze solid or have low oxygen concentrations in the winter. The species composition of fish found in the Saskatchewan drainage is similar to that of the Mackenzie drainage previously discussed. Brook stickleback, fathead minnow, and sauger are common in many of the streams. The small streams are important spawning areas for various suckers, minnows, brook stickleback and fathead minnow. A list of fishes found in the Saskatchewan drainage is given in Table 2.1.2.7-6.

Shortly before entering the United States, the proposed Monchy Delivery Line crosses the Frenchman River, a tributary of the Milk River. The area is semiarid and has few permanent streams. The fauna is similar to that of the South Saskatchewan River. A list of fishes found in this drainage in Alberta is given in Table 2.1.2.7-7.

Columbia River Drainage

The southern part of the proposed Kingsgate Delivery Line, from the Continental Divide to the Canada-United States border, crosses the Columbia River drainage. The only major river crossed would be the Kootenay River. The area is mountainous, except for the valley of the Kootenay River. The fauna is dominated by salmonids, especially Dolly Varden char, cutthroat trout and mountain whitefish. A list of species found in the Kootenay River system is given in Table 2.1.2.7-8.

Table 2.1.2.7-5 Domestic catches of fish at locations in the Mackenzie Valley during 1972

Location	Pounds
Jean Marie	800
Trout Lake	1,000
Fort Simpson	1,000
Fort Wrigley	2,500
Fort Norman	29,000
Fort Good Hope	100,000
Arctic Red River	450,000
Inuvik	111,000

Table 2.1.2.7-6 Fish found in the Saskatchewan River drainage in Alberta

Species	
Common name	Scientific name
Lake sturgeon	*Acipenser fulvescens*
Lake cisco	*Coregonus artedii*
Lake whitefish	*Coregonus clupeaformis*
Mountain whitefish	*Prosopium williamsoni*
Lake trout	*Salvelinus namaycush*
Dolly varden	*Salvelinus malma*
Brook trout	*Salvelinus fontinalis*
Brown trout	*Salmo trutto*
Cutthroat trout	*Salmo clarki*
Rainbow trout	*Salmo gairdneri*
Golden trout	*Salmo aguabonita*
Kokanee	*Oncorhynchus nerka*
Northern pike	*Esox lucius*
Goldeye	*Hiodon alosoides*
Longnose dace	*Rhinichthys cataractae*
Flathead chub	*Hybopsis gracilis*
Lake chub	*Couesius plumbeus*
Pearl dace	*Semotilus margarita*
Northern redbelly dace	*Phoxinus eos*
Finescale dace	*Phoxinus neogaeus*
Fathead minnow	*Pimephales promelas*
Emerald shiner	*Notropis atherinoides*
River shiner	*Notropis blennius*
Spottail shiner	*Notropis blennius*
Silvery minnow	*Hybognathus nuchalis*

Table 2.1.2.7-6 (Continued)

Species	
Common name	Scientific name
Quillback	*Carpiodes carpio*
Silver redhorse	*Moxostoma anisurum*
Northern redhorse	*Moxostoma macrolepidotum*
Longnose sucker	*Catostomus catostomus*
White sucker	*Catostomus commersoni*
Mountain sucker	*Catostomus platyrhynchus*
Burbot	*Lota lota*
Troutperch	*Percopsis omiscomaycus*
Brook stickleback	*Culea inconstans*
Iowa darter	*Etheostoma exile*
Yellow perch	*Perca flavescens*
Sauger	*Stizostedion canadense*
Walleye	*Stizostedion vitreum*
Slimy sculpin	*Cottus cognatus*
Spoonhead sculpin	*Cottus ricei*

Table 2.1.2.7-7 Fish found in the Missouri River drainage in Alberta

Species	
Common name	Scientific name
Mountain whitefish	*Prosopium williamsoni*
Cutthroat trout	*Salmo clarki*
Rainbow trout	*Salmo gairdneri*
Northern pike	*Esox lucius*
Longnose dace	*Rhinichthys cataractae*
Flathead chub	*Hybopsis gracilis*
Lake chub	*Couesius plumbeus*
Northern redbelly dace	*Phoxinus eos*
Finescale dace	*Phoxinus neogaeus*
Flathead minnow	*Pimephales promelas*
Brassy minnow	*Hybognathus hankinsoni*
Silvery minnow	*Hybognathus nuchalis*
Longnose sucker	*Catostomus catostomus*
White sucker	*Catostomus commersoni*
Mountain sucker	*Catostomus platyrhynchus*
Stonecat	*Noturus flavus*
Burbot	*Lota lota*
Brook stickleback	*Culeo inconstans*
Iowa darter	*Etheostoma exile*
Sauger	*Stizostedion canadense*
Mottled sculpin	*Cottus bairdi*
Spoonhead sculpin	*Cottus ricei*

Table 2.1.2.7-8 Fish found in the Columbia River drainage

Species	
Common name	Scientific name
White sturgeon	*Acipenser transmontanus*
Lake whitefish	*Coregonus clupeaformis*
Mountain whitefish	*Prosopium williamsoni*
Pygmy whitefish	*Prosopium coulteri*
Kokanee	*Oncorhynchus nerka*
Cutthroat trout	*Salmo clarki*
Rainbow trout	*Salmo gairdneri*
Brook trout	*Salvelinus fontinalis*
Dolly Varden	*Salvelinus malma*
Lake trout	*Salvelinus namaycush*
Peamouth	*Mylocheilus caurinus*
Northern squawfish	*Ptychocheilus oregonensis*
Longnose dace	*Rhinichthys cataractae*
Redside shiner	*Richardsonius balteatus*
Longnose sucker	*Catostomus catostomus*
Largescale sucker	*Catostomus macrocheilus*
Black bullhead	*Ictalurus melas*
Burbot	*Lota lota*
Pumpkinseed	*Lepomis gibbosus*
Largemouth bass	*Micropterus salmoides*
Yellow perch	*Perca flavescens*
Slimy sculpin	*Cottus cognatus*
Torrent sculpin	*Cottus rhotheus*

Mammals

The distribution of the mammalian fauna (Hall and Kelson, 1959; Banfield, 1974) along the proposed route through the Mackenzie Valley and southward to the Canada-United States border is listed by species and by segment of the route in Table 2.1.2.7-9. In this table, species are grouped as large herbivores, small herbivores, carnivores and insectivores; they are discussed in Section 3.1.2.7.

North of 60° N Latitude

The proposed Prudhoe Bay Supply Line traverses important caribou calving areas and migration routes. The calving grounds include the coastal plain and the foothills to an elevation of about 3,500 feet west of the Babbage River. Caribou reach this calving ground from the east, following the Richardson Mountains into the foothills of the Barn and British Mountains, and from the south across the Old Crow Flats into the north-south oriented drainages. From this calving area herds of as many as 60,000 animals move west into Alaska. The coastal plain-foothills area is not prime winter caribou range.

The Yukon Coastal Plain is prime habitat for the arctic fox. The valleys of Craig Creek, Malcolm River, and Firth River are the northernmost moose range in Canada. Musk oxen from the Alaskan herd stray into the area and may become established soon. Other mammals present include wolves, wolverines, red foxes, weasels, hares, and small rodents. Grizzly bears are common along the mountain slopes and venture onto the Yukon Coastal Plain at many points along the Prudhoe Bay Supply Line.

Near the mouth of the Blow River the coastal plain is restricted by the foothills of the Richardson Mountains to a width of only a few miles; the proposed route runs 10-12 miles inland from the coast across tundra dissected by vallies supporting shrubbery cover. This area contains grizzly bear, arctic ground squirrel, red fox, and arctic fox. Near the Fish River the proposed route turns almost due south, skirting the western edge of the vast Mackenzie Delta for about 70 miles and running alternately through forested foothills and across streams, marshes, flats and alluvial fans of the delta. This section is home not only to the forest-dwelling mammals but to those which range over both forest and tundra, including mink, wolves, wolverine, red foxes, weasels, hares and small rodents. Grizzly bears are common on the uplands and Dall sheep are found at higher elevations. Beavers are numerous in the streams and white whales use Shallow Bay as a calving area. Spring and fall migrations of barren-ground caribou can be expected throughout the Richardson Mountains.

From Fort McPherson to the Arctic Red River the proposed route leaves the Mackenzie Delta and runs generally east across some 40 miles of Boreal Forest and Forest-Tundra. Here, muskrat and beaver are more numerous and the large Mackenzie Delta mink is common, while Dall sheep, caribou, grizzly bear and arctic fox are scarce or absent.

The 143-mile-long Richards Island Supply Line would cross terrain that generally alternates between forested upland, tundra, and aquatic habitats. Consequently the diversity of mammal species is impressive, ranging from black bear, lynx, squirrels, small rodents and marten in the coniferous forests to wolves, wolverines, red and arctic foxes, weasels, hares and other species which inhabit both forest and open tundra. Grizzly bear are common, and moose have also been observed

Table 2.1.2.7-9 Mammal species known or possibly occurring along segments of the proposed route and marine species that might be influenced directly or indirectly by construction, operation, or other activities associated with building the pipeline

Species		Occurrence along pipeline segments							
		I[1]	I-A	II	III	IV	V	VI	VII
Common name	Scientific name	Prudhoe Bay supply line	Interior Alternative	Richards Island supply line	Main line (N. Mackenzie)	Main line (S. Mackenzie)	Main line (Alberta)	Kingsgate Del. line	Monchy Del. line
Large Herbivorous Species									
Wapiti	Cervus canadensis						X	X	
Mule deer	Odocoileus hemionus					X	X	X	
White-tailed deer	O. virginianus								X
Moose	Alces alces	X	X	X	X	X	X	X	
Caribou	Rangifer tarandus	X	X	X	X	X	X		
Pronghorn	Antilocapra americana								X
*Muskox	Ovibos moschatus	X							
Dall's sheep	Ovis dalli				X	X			
Bighorn sheep	O. canadensis							X	
Small Herbivorous Species									
Collared pika	Ochotona collaris		X			X			
Pika	O. princeps							X	
Nuttall's cottontail rabbit	Sylvilagus nuttallii							X	X
Snowshoe rabbit	Lepus americanus			X	X	X	X	X	
Arctic hare	L. arcticus			X	X				
White-tailed jackrabbit	Lepus townsendi							X	X
Hoary marmot	Marmota caligata		X		X				
Woodchuck	M. monax					X	X	X	
Yellow-bellied marmot	M. flaviventris							X	
Least chipmunk	Eutamias minimus				X	X	X	X	X
Yellow pine chipmunk	E. amoenus							X	
Red-tailed chipmunk	E. ruficaudus							X	
Richardson's ground-squirrel	Spermophilus richardsonii						X	X	X

[1] Delta portion included with II; this allows comparisons of distribution between Prudhoe Bay Supply Line (Proposed Route) and the alternative Interior Route, IA.

*Discussed under "Rare and Endangered Species," in subsection 3.1.2.7.

Table 2.1.2.7-9 (Continued)

Species		Pipeline segments							
Common name	Scientific name	I	I-A	II	III	IV	V	VI	VII
Columbian groundsquirrel	*S. columbianus*							X	
Arctic groundsquirrel	*S. undulatus*	X	X	X	X	X			
Thirteen-lined ground-squirrel	*S. tridecemlineatus*						X	X	X
Golden-mantled ground-squirrel	*S. lateralis*							X	
*Black-tailed prairiedog	*Cynomys ludovicianus*								X
Red squirrel	*Tamiasciurus hudsonicus*		X		X	X	X	X	
Flying squirrel	*Glaucomys sabrinus*				X	X	X	X	
Beaver	*Castor canadensis*		X	X	X	X	X	X	X
Northern pocket gopher	*Thomomys talpoides*				X	X	X	X	
Olive-backed pocket mouse	*Perognathus fasciatus*								X
Deer mouse	*Peromyscus maniculatus*				X	X	X	X	X
	P. leucopus								X
Harvest-mouse	*Reithrodontomys megalotis*								X
Grasshopper mouse	*Onychomys leucogaster*								X
Bushy-tailed woodrat	*Neotoma cinerea*						X	X	
Gapper's red-backed vole	*Clethrionomys gapperi*					X	X	X	
Northern red-backed vole	*C. rutilus*	X	X	X	X	X			
Heather vole	*Phenacomys intermedius*				X	X	X	X	
Meadow vole	*Microtus pennsylvanicus*			X	X	X	X	X	X
Tundra vole	*Microtus oeconomus*	X	X	X	X				
Singing vole	*M. miurus*		X		X				
Yellow-cheeked vole	*Microtus xanthognathus*		X		X	X	X		
Prairie vole	*M. ochrogaster*						?		?
Longtail vole	*M. longicaudis*							X	
Water vole	*M. richardsoni*							X	
Sagebrush vole	*Lagurus curtatus*								X
Muskrat	*Ondatra zibethicus*		X	X	X	X	X	X	X
Brown lemming	*Lemmus trimucronatus*	X	X	X	X	X			
Northern bog lemming	*Synaptomys borealis*				X	X	X	X	
Collared lemming	*Dicrostonyx groenlandicus*	X	X	X	X				
Norway rat	*Rattus norvegicus*								
House mouse	*Mus musculus*								

Table 2.1.2.7-9 (Continued)

Species		Pipeline segments							
Common name	Scientific name	I	I-A	II	III	IV	V	VI	VII
Meadow jumping mouse	Zapus hudsonius					X	X		
Western jumping mouse	Z. princeps						X	X	X
Porcupine	Erethizon dorsatum	X	X	X	X	X	X	X	X
Wolf	Canis lupus	X	X	X	X	X	X	X	
Coyote	C. latrans	X	X	X	X	X	X	X	X
Arctic fox	Alopex lagopus	X	X	X	X	X	X		
Red fox	Vulpes fulva	X	X	X	X	X	X	X	
*Kit fox	V. velox							X	X
Black bear	Ursus americanus			X	X	X	X	X	
Grizzly bear	U. arctos	X	X	X	X	X	X	X	
Polar bear	Thalarctos maritimus	X							
Racoon	Procyon lotor								X
Marten	Martes americana		X		X	X	X	X	
Fisher	M. pennanti					X	X	X	
Ermine	Mustela ermina	X	X	X	X	X	X	X	
Least/weasel	M. rixosa	X	X	X	X	X	X	X	
Long-tailed weasel	M. frenata					X	X	X	
Black-footed ferret	M. nigrepes								X
Mink	Mustela vison	X	X	X	X	X	X	X	X
*Wolverine	Gulo luscus	X	X	X	X	X	X	X	X
Badger	Taxidea taxus						X	X	X
Striped skunk	Mephitis mephitis					X	X	X	X
*River otter	Lutra canadensis				X	X	X	X	X
*Mountain lion	Felis concolor					X	X	X	
Lynx	Lynx canadensis	X	X	X	X	X	X	X	
Bobcat	L. rufus						X	X	
Insectivorous Species									
Masked shrew	Sorex cinereus	X	X	X	X	X	X	X	X
Dusky shrew	S. vagrans		X	X	X	X	X	X	X
Water shrew	S. palustris						X	X	
Arctic shrew	S. arcticus	X	X	X	X	X	X		
Pigmy shrew	Microsorex hoy					X	X	X	

Table 2.1.2.7-9 (Continued)

Species		Pipeline segments							
Common name	Scientific name	I	I-A	II	III	IV	V	VI	VII
Little brown Myotis	*Myotis lucifugus*					X	X	X	X
Long-eared Myotis	*M. evotis*						X	X	X
Long-legged Myotis	*M. volans*						X	X	X
Small-footed Myotis	*M. subulatus*							X	
Silver-haired bat	*Lasionycteris noctivagans*						X	X	X
Big Brown bat	*Eptesicus fuscus*						X	X	X
Red bat	*Lasiurus borealis*								X
Hoary bat	*L. cinerus*							X	X
Marine Species		Beaufort Sea							
Walrus	*Odobenus rosmarus*	?							
Bearded seal	*Erignathus barbatus*	X		X					
Harbour seal	*Phoca vitulina*	X		X					
Ringed seal	*P. hispida*	X		X					
Harp seal	*P. groenlandica*			?					
White whale	*Delphinapterus leucas*	X		X					
Narwhal	*Monodon monoceros*	?		?					
Bowhead whale	*Balaena mysticetus*	X							

along the route. The area skirts the seasonal range of the Bluenose caribou herd.

The part of the Prudhoe Bay Supply Line from Arctic Red River to Travaillant Lake and that part of the Northern Mackenzie segment of the proposed Main Line between Travaillant Lake and Fort Good Hope are not significantly different in terms of the mammal species they support. Forest species, including black bear, lynx, squirrels and small rodents, are common and marten are numerous. Beaver and muskrat are numerous in the lakes and streams but mink and otter are less abundant. Moose are abundant in their preferred habitat, particularly along the Mackenzie River and its tributaries. Prescott et al. (1973) noted this to be year-round range for woodland caribou, barren ground caribou and feral reindeer.

For the remaining part of the Northern Mackenzie segment of the Main Line, from Fort Good Hope to Norman Wells, scattered coniferous forests support the previously described forest species, but for the most part the mammals of this section are the forest-open tundra types, notably wolves, wolverines, foxes, weasels, hares and small rodents. It is not good moose, caribou, Dall sheep or grizzly bear habitat.

The Southern Mackenzie segment extends from Norman Wells to 60° N latitude. Between Norman Wells and River Between Two Mountains mammal species are numerous and diverse, including black bear, lynx, squirrels, marten, hares, weasels, wolves, wolverines, red foxes, and small rodents. Beaver and muskrat occur in abundance but mink and otter are scarce. Moose occur in abundance but grizzly bears and caribou occur only sparsely.

For the remaining part of the Southern Mackenzie segment, forest species such as black bear, lynx and marten are especially abundant. Wetland species such as beaver, muskrat, otter and mink are numerous since their preferred aquatic habitats are widespread. Moose are common, woodland caribou occur locally and grizzly bear are absent.

South of 60° N Latitude

Moose are abundant from northern Alberta to Caroline Junction on the Main Line and west of the Porcupine Hills on the Kingsgate Delivery Line, but are lacking on the proposed Monchy Delivery Line.

Woodland caribou, being dependent on mature spruce forests, are reported only in the areas of Bistcho Lake and Chinchaga River along the Main Line.

Elk are found along the Main Line south of the Peace River crossing, and along the Kingsgate Delivery Line. They do not occur in extreme northern Alberta or along the Monchy Delivery Line.

Bighorn sheep are present in the Livingston Range of southern Alberta along the Kingsgate Delivery Line; good sheep habitat is also found where this route crosses high ridges between Dutch and Racehorse Creeks.

Both mule deer and whitetail deer are found nearly everywhere along the proposed route south of 60° N latitude, particularly in and south of the Peace River valley.

Pronghorn antelope are found principally along the Monchy Delivery Line. However, the only winter ranges on the proposed route are in the Middle Sand Hills and near the South Saskatchewan River crossing.

Birds

A total of about 320 of the 518 species of birds known to have occurred in Canada could be encountered along the proposed route between the Beaufort Sea Coast and the Canada-United States border. Table 2.1.2.7-10 lists common and scientific names according to the American Ornithologists Union (1957, 1973) and the distribution data tabulated for north of 60° N latitude (Jacobsen, 1974) and for south of 60° N latitude (Godfrey, 1966; Salt and Wilk, 1958).

Prudhoe Bay Supply Line

From the Alaska-Yukon border the proposed route traverses the boundary between the lower foothill slopes of the British Mountains and the Yukon Coastal Plain. At least 85 species of birds from 22 families have been reported as nesters, migrants, or visitors along the coastal plain (Table 2.1.2.7-10).

The Yukon Coastal Plain contains habitat critical to hundreds of thousands of geese, ducks, loons, and shorebirds for nesting and spring and fall migrations. The tundra lakes, from June through August, are major brood-rearing and molting areas for these species. Brant, eider, gulls, and terns nest on spits, lagoons, beaches and islands in June and July, and from July through September scoters, oldsquaw, eider, and scaup molt here, and brant, ducks, loons, and shorebirds stage and migrate from these waters. Several hundred thousand snow geese use this Arctic Coastal Plain from Shingle Point in the Yukon Territory to the Canning River in Alaska for staging and feeding from mid-August to early October. The Yukon Coastal Plain and the British Mountains also contain several peregrine falcon, gyrfalcon and golden eagle eyries.

Upon leaving the Yukon Coastal Plain the proposed route skirts the Mackenzie Delta as far as Fort McPherson. The Mackenzie Delta is one of the major waterfowl production areas of North America, and supports an annual breeding waterfowl population of 100,000-350,000 ducks and geese, and more than 20,000 whistling swans. It supplies waterfowl to all four North American flyways (Jacobson, 1974). The shallow Mackenzie Bay area is especially critical nesting and molting habitat for whistling swans. Bald eagles nest on the Mackenzie Delta; the Peel Plateau and Richardson Mountains contain active peregrine falcon and golden eagle eyries. Approximately 139 species of birds from 31 families have been reported in the delta according to Jacobson (1974).

From the Peel River at Fort McPherson the proposed route would be generally on the upper slopes of the Arctic Red River valley. Little aquatic habitat is present on this portion of the route. However, from the Arctic Red River to the junction with the Richards Island Supply Line west of Travaillant Lake, the alignment would cross a maze of lakes, streams and aquatic environments.

The upland, forested portions of this section are commonly used by nesting eagles, peregrine falcons and gyrfalcons as well as a host

Table 2.1.2.7-10 Bird species known or expected along segments of proposed route; includes winter areas

Species		Type of occurrence along pipeline segments[1]							
		I[2]	IA	II	III	IV	V	VI	VII
COMMON NAME	SCIENTIFIC NAME	Prudhoe Bay Supply Line	Interior Alternative	Richards Is. Supply Line	Main Line (N. Mackenzie)	Main Line (S. Mackenzie)	Main Line (Alberta)	Kingsgate Del. Line	Monchy Del. Line
Common Loon	*Gavia immer*	B?	B	B	B	B	B		
Yellow-billed Loon	*Gavia adamsii*	B		B	M	M	M		
Arctic Loon	*Gavia arctica*	B	B	B	B	B	M		
Red-throated Loon	*Gavia stellata*	B	B	B	B	B	M		
Red-necked Grebe	*Podiceps grisegena*		B	B	B	B	B		
Horned Grebe	*Podiceps auritus*		B	B	B	B	B	B	
Eared Grebe	*Podiceps caspicus*						V	B	B?
Pied-billed Grebe	*Podilymbus podiceps*					V	B	B	
Western Grebe	*Acchmophorus occidentalia*						B	V	V
White Pelican	*Pelecanus erythrorhychos*					V	V	V	V
Double-crested Cormorant	*Phalacrocorax auritus*						V	V	B
Pelagic Cormorant	*Phalacrocorax pelagicus*	V							B
Great Blue Heron	*Ardea heredias*						B	B	B
Black-Crowned Night Heron	*Nycticorax nycticorax*						V	V	B
American Bittern	*Botaurus lentiginosus*					V	B	B	B
Whistling Swan	*Olor columbianus*	B	B	B	M	M	M		

[1] B = breeding populations; M = migrants; V = visitants; ? = uncertain occurrence.

[2] Delta portion included with II; this allows comparisons of distribution between Prudhoe Bay Supply Line (Proposed Route) and alternative Interior Route, IA.

Table 2.1.2.7-10 (Continued)

COMMON NAME	SCIENTIFIC NAME	I	IA	II	III	IV	V	VI	VII
Trumpeter Swan	Olor canadensis			B	M	M	M		
Canada Goose	Branta canadensis	B	B	B	B	B	B	B	B
Black Brant	Branta bernicla	B	B	B					
White-fronted Goose	Anser albifrons	B	B	B	M	M	M	M	M
Snow Goose	Chen caerulescens	M	M	B	M	M	M	M	M
Ross' Goose	Chen rossii			M	M	M	M	M	M
Mallard	Anas platyrhynchos	B	B	B	B	B	B	B	B
Gadwall	Anas strepera				V	V	B	B	B
Pintail	Anas acuta	B	B	B	B	B	B	B	B
Eurasian Green-winged Teal	Anas crecca crecca			V					
American Green-winged Teal	Anas crecca carolinensis	B	B	B	B	B	B	B	B
Blue-winged Teal	Anas discors					B	B	B	B
Cinnamon Teal	Anas cyanoptera						B	B	B
European Wigeon	Anas penelope				V				
American Wigeon	Anas americana	B	B	B	B	B	B	B	B
Shoveler	Anas clypeata	V	B	B	B	B	B	B	B
Wood Duck	Aix sponsa							B	B
Redhead	Aythya americana					B	B	V	B
Ring-necked Duck	Aythya collaris				B?	B	B	B	
Canvasback	Aythya valisineria	V	B	B	B	B	B		B
Greater Scaup	Aythya matila	B	B	B	B	B			
Lesser Scaup	Aythya affinis	V	B	B	B	B	B	B?	B?
Common Goldeneye	Bucephala clangula		B	B	B	B	B	M	M
Barrow's Goldeneye	Bucephala islandica				V	B		B	
Bufflehead	Bucephalis albeola			V	B	B	B	B	B
Oldsquaw	Clangula hyemalis	B	B	B	M	M	M	M	M
Harlequin Duck	Histrionicus histrionicus	B	B	V	V	V	V	B	V
Common Eider	Somateria mollissima	B		B					
King Eider	Somateria spectabilis	B		B					
Spectacled Eider	Somateria fishcheri	V?							
White-winged Scoter	Melanitta deglandi	B	B	B	B	B	B	B	B
Surf Scoter	Melanitta perspicillata	B	B	B	B	B	B	B?	B

Table 2.1.2.7-10 (Continued)

COMMON NAME	SCIENTIFIC NAME	I	IA	II	III	IV	V	VI	VII
Black Scoter	Mellanitta nigra	V		V	V	V			
Ruddy Duck	Oxyura jamaicensis					B			
Hooded Merganser	Lophodytes cucullatus					V			
Common Merganser	Mergus merganser			V	V	B			
Red-breasted Merganser	Mergus serrator	B	B	B	B	B	B	M	M
Turkey Vulture	Cathartes aura							B	B
Goshawk	Accipiter gentilis		B	B	B	B	B	B	V
Cooper's Hawk	Accipiter coperii						B	B	
Sharp-shinned Hawk	Accipiter striatus		B	B	B	B	B	B	B
Red-tailed Hawk	Buteo jamaicensis			B	B	B	B	B	B
Swainson's Hawk	Buteo swainsoni				V	V	B	B	B
Ferruginous Hawk	Buteo regalis						B	B	B
Rough-legged Hawk	Buteo lagopus	B	B	B	M	M	M	M	M
*Golden Eagle	Aquila chrysaetos	B	B	B	B	M	B	B	B
*Bald Eagle	Haliaetus leucocephalus	V	B	B	B	B	B	V	V
Marsh Hawk	Circus cyaneus	V	B	B	B	B	B	B	B
Osprey	Pandion haliaetus		B		B	B	B	B	M
*Gyrfalcon	Falco rusticolus	B	B	B	V	V	V	V	V
Prairie Falcon	Falco mexicanus						B	B	B
*Peregrine Falcon	Falco peregrinus	B	B	B	B	B	B	B	B
*Merlin	Falco columbarius		B	B	B	B	B	B	B
American Kestrel	Falco sparvarius		V	V	B	B	B	B	B
Wild Turkey	Meleagris gallopavo								B
Blue Grouse	Dendragapus obscurus					B	B	B	
Spruce Grouse	Canachites canadensis		B		B	B	B	B	
Ruffed Grouse	Bonasa umbellus		B		B	B	B	B	B
Willow Ptarmigan	Lagopus lagopus	B	B	B	B	V	V		
White-tailed Ptarmigan	Lagopus leucurus							B	
Rock Ptarmigan	Lagopus mutus	B	B	B					
Greater Prairie Chicken	Tympanuchus cupido							?	?

*Discussed under "Rare and Endangered Species," in subsection 3.1.2.7

Table 2.1.2.7-10 (Continued)

COMMON NAME	SCIENTIFIC NAME	I	IA	II	III	IV	V	VI	VII
Sharp-tailed Grouse	_Pedioecetes phasianellus_		B?		B	B	B	B	B
Sage Grouse	_Centrocercus urophasianus_								B
	Phasianus colchius						B	B	B
Gray Partridge	_Perdix perdix_						B	B	B
*Whooping Crane	_Grus americana_					V			M
Sandhill Crane	_Grus canadensis_	B		B	B	B	B	B?	M
Sora	_Porzana carolina_			V	B?	B	B	B	B
Yellow Rail	_Coturnicops noveboracensis_					V	B	M	M
Virginia Rail	_Rallus limicola_							B?	B
American Coot	_Fulica americana_					V?	B	B	B
Semipalmated Plover	_Charadrius semipalmatus_	B	B	B	B	B	M	M	M
Piping Plover	_C. melodus_							B?	B?
Killdeer	_Charadrius vociferus_			V	V	B	B	B	B
American Golden Plover	_Pluvialis dominica_	B	B	B	B	M	M	M	M
Black-bellied Plover	_Pluvialis squatarola_	B		M	M	M	M	M	M
Ruddy Turnstone	_Arenaria interpres_	B		M	M	M	M	M	M
Common Snipe	_Capella gallinago_	B	B	B	B	B	B	B	B
Whimbrel	_Numenius phaeopus_	B	B	B	M	M	M	M	M
*Eskimo Curlew	_Numenius borealis_					M?			
Long-billed Curlew	_N. americanus_								B
Upland Plover	_Bartramia longicauda_		B			B	B	B	B
Spotted Sandpiper	_Actitis macularia_		B	B	B	B	B	B	B
Solitary Sandpiper	_Tringa solitaria_		B	B	B	B	B	M	M
Wandering Tattler	_Heteroscelus incanus_		B				V		
Willet	_Catoptrophorus semipalmatus_								B
Greater Yellowlegs	_Trigna melanoleucus_			V		V	B	M	M
Lesser Yellowlegs	_Trigna flavipes_	V	B	B	B	B	B	M	M
Knot	_Calidris canutus_		V	V					M
Pectoral Sandpiper	_Calidris melanotos_	B		B	M	M	M	M	M
White-rumped Sandpiper	_Calidris fuscicollis_	B		B?	M	M	M	M	M
Baird's Sandpiper	_Calidris bairdii_	B	B	B	M	M	M	M	M
Least Sandpiper	_Calidris minutilla_	B	B	B	M	M	M	M	M
Dunlin	_Calidris alpina_	B		B	M	M	M	M	M
Short-billed Dowitcher	_Limnodromus griseus_					B	B	M	M

Table 2.1.2.7-10 (Continued)

COMMON NAME	SCIENTIFIC NAME	I	IA	II	III	IV	V	VI	VII
Long-billed Dowitcher	*Limnodromus scolopaceus*	B?		B	M	M	M	M	M
Stilt Sandpiper	*Micropalama himantopus*	V		B?	M	M	M	M	M
Semipalmated Sandpiper	*Calidris puscillus*	B		B	M	M	M	M	M
Buff-breasted Sandpiper	*Tryngites subruficollis*	B		M	M	M	M	M	M
Marbled Godwit	*Limosa fedoa*								B
Hudsonian Godwit	*Limosa naemastica*	B		B	M	M	M	M	M
Sanderling	*Calidris alba*	M		M	M	M	M	M	M
Avocet	*Recurvirostra americana*							B?	B
Red Phalarope	*Phalaropus fulicarius*	B?	B						
Wilson's Phalarope	*Steaenopus tricolor*						B	B	B
Northern Phalarope	*Lobipes lobatus*	B		B	B	M	M	M	M
Pomarine Jaegar	*Stercorarius pomarinus*	M		M					
Parasitic Jaegar	*Stercorarius parasiticus*	B	V	B	M		V		
Long-tailed Jaegar	*Stercorarius longicaudus*	B	B?	B	V		V		
Glaucous Gull	*Larus hyperboreus*	B		B	M	M			
Herring Gull	*Larus argentatus*	B	V	B	B	B	M	M	M
Thayer's Gull	*Larus thayeri*	M							
California Gull	*Larus californicus*					V	V	V	B
Ring-billed Gull	*Larus delawarensis*			V		V	B	B	B
Mew Gull	*Larus canus*	B		B	B	B	M	M	
Franklin's Gull	*Larux pipixcan*			V			B		B
Bonaparte's Gull	*Larux philadelphia*			B	B	B	B	M	M
Sabine's Gull	*Zema sabini*			B			V		
Forster's Tern	*Sterna forsteri*						B?	V	V
Common tern	*Sterna hirundo*					B	B	B	B
Arctic tern	*Sterna paradisaea*	B	B	B	B	B			
Caspian tern	*Hydroprogne caspia*					V	V		
Black Tern	*Chlidonias niger*				V	B	B	B	B
Thick-billed Murre	*Uria lomvia*	V							
Black Guillemot	*Cepphus grylle*	B							
Least Auklet	*Aethia pusilla*	V		V					
Mourning Dove	*Zenaida macroura*					V	B	B	B
Black-billed Cuckoo	*Coccyzus erythropthalmus*						V	V	B

Table 2.1.2.7-10 (Continued)

COMMON NAME	SCIENTIFIC NAME	I	IA	II	III	IV	V	VI	VII
Great Horned Owl	_Bubo virginianus_		V	B	B	B	B	B	B
Snowy Owl	_Nyctea scandiaca_	B		B	V	V	V	V	V
Hawk Owl	_Surnia ulula_		B	B	B	B	B	M	M
Pigmy Owl	_Glaucidium gnoma_							B	
Burrowing Owl	_Speotyto cuniculara_								B
Barred Owl	_Strix varia_						B	V	
Great Gray Owl	_Strix nebulosa_		B		B	B	B	B	
Long-eared Owl	_Asio otus_					B	B	B	B
Short-eared Owl	_Asio flammeus_	B	B	B	B	B	B	B	B
Boreal Owl	_Aegolius funereus_		B?	B?	B	B	B	B?	
Saw Whet Owl	_A. acadicus_						B	B	B
Common Nighthawk	_Chordeiles minor_					B	B	B	B
Black Swift	_Cypseloides niger_							B	
Vauxi Swift	_Chaetura vauxi_							B	
Ruby-throated Hummingbird	_Archilochus colubris_						B		B
Rufus Hummingbird	_Selasphorus rufus_							B	
Calliope Hummingbird	_Stellula calliope_							B	
Belted Kingfisher	_Megacervle alcyon_		V	B?	B	B	B	B	B
Common Flicker	_Colaptes auratus_		B	B	B	B	B	B	B
Pileated Woodpecker	_Dryocopus pileatus_					B	B	B	
Yellow-bellied	_Sphyrapicus varius_				V	B	B	B	
Williamson's Sapsucker	_S. thyriodeus_							B	
Red-headed Woodpecker	_Melanerpes erythrocephalus_								B
Lewis's Woodpecker	_Asyndesmus lewsi_							B	
Hairy Woodpecker	_Dendrocopos villosus_				V	B	B	B	B
Downy Woodpecker	_Dendrocopos pubescens_					B	B	B	B
Black-backed Three-toed Woodpecker	_Picoides arcticus_				V	B	B	B?	
Northern Three-toed Woodpecker	_Picoides tridactylus_		B	B	B	B	B	B	
Eastern Kingbird	_Tyrannus tyrannus_				B	B	B	B	B
Western Kingbird	_T. verticalis_							B	B

Table 2.1.2.7-10 (Continued)

COMMON NAME	SCIENTIFIC NAME	I	IA	II	III	IV	V	VI	VII
Eastern Phoebe	Sayornis phoebe					B	B	B?	M
Say's Phoebe	Sayornis saya		B	B	B	B	B	B	B
Yellow-bellied Flycatcher	Empidonax flaviventris					B	B	B	B
Alder Flycatcher	Empidonax alnorum		B	B	B	B	B	B	B
Least Flycatcher	Empidonax minimus					B	B	B	B
Hammond's Flycatcher	E. hammondii							B	
Dusky Flycatcher	E. oberholseri							B	B
Western Flycatcher	E. difficilis							B	
Western Wood Pewee	Contopus sordidulus					B	B	B	B
Olive-sided Flycatcher	Nuttallornis borealis		V	V	V	B	B	B	
Horned Lark	Eremophila alpestris	B	B	B	M	M	B	B	B
Violet-green Swallow	Tachycineta thalassina		B					B	B
Tree Swallow	Iridoprocne bicolor	V	B	B	B	B	B	B	B
Bank Swallow	Riparia riparia		B	B	B	B	B	B	B
Rough-winged Swallow	Stelgidopterux ruficollis							B	B
Barn Swallow	Hirudino rustica				V	B	B	B	B
Cliff Swallow	Petrochelidon pyrrhonota	B	B	B	B	B	B	B	B
Purple Martin	Progne subis						B		
Gray Jay	Perisoreus canadensis		B	B	B	B	B	B	
Blue Jay	Cyanocitta cristata						B		
Steller's Jay	C. stelleri							B	
Black-billed Magpie	Pica pica				V	B	B	B	B
Common Raven	Corvus corax	B	B	B	B	B	B	B	
Common Crow	Corvus brachyrhychos					B	B	B	B
Clark's Nutcracker	Nucifraga columbiana							B	
Black-capped Chickadee	Parus atricapillus					B	B	B	B
Mountain Chickadee	P. gambeli							B	
Gray-headed Chickadee	Parus cinctus		B	B					
Boreal Chickadee	Parus Hudsonicus		B	B	B	B	B	B	
White-breasted Nuthatch	Sitta carolinensis							B	

Table 2.1.2.7-10 (Continued)

COMMON NAME	SCIENTIFIC NAME	I	IA	II	III	IV	V	VI	VII
Red-breasted Nuthatch	Sitta cannadensis					B	B	B	B
Pigmy Nuthatch	S. pygmea							B	
Brown Creeper	Certhia Familiaris						B	B	
Dipper	Cinclus mexicanus						B		
House Wren	Troglodytes aedon						B	B	B
Winter Wren	Troglodytes Troglodytes					V	V	B	
Long-billed Marsh Wren	Telmatodytes palustris						B	B?	B
Rock Wren	Salpinetes obsoletus								B
Mocking Bird	Mimus polyglottos						B		
Catbird	Dumetella carolinenis						B	B	B
Brown Thrasher	Toxostoma rufum							V	B
Sage Thrasher	Oreoscoptes montanns								B
American Robin	Turdus migratorius		B	B	B	B	B	B	B
Varied Thrush	Lxoreus naevius		B	B	B	B	M	B	M
Hermit Thrush	Catharus guttata				V	B	B	B	
Swainson's Thrush	Catharus ustulata		B		B	B	B	B	B
Gray-cheeked Thrush	Catharus minimus		B	B	B	B	M	M	M
Veery	Catharus fuscescens						B	B	B
Eastern Bluebird	Sialia sialis								B
Western Bluebird	Sialia mexicana							B	
Mountain Bluebird	S. currucoides						B	B	B
Wheatear	Oenanthe oenanthe		B						
Bluethroat	Luscinia svecica	V							
Townsend's Solitaire	Myadestes towsendi				V		V	B	V
Golden-crowned Kinglet	Regulus satrapa						B	B	
Ruby-crowned Kinglet	Regulus calendula		B?	B	B	B	B	B	
White Wagtail	Motacilla alps		V						
Yellow Wagtail	Motacilla flava	B							
Water Pipit	Anthus spinoletta	B	B	B	M	M	M	M	M
Sprague's Pipit	A. spragueii					B	B?	B	M
Bohemian Waxwing	Bombycilla garruius		B	B	B	B	B	B	M
Cedar Waxwing	Bombycilla cedrorum				V	B	B	B	M
Northern Shrike	Lanius excubitor		B?	B	B	B	M	V	V
Loggerhead Shrike	L. Ludovicianus						B	V	B

Table 2.1.2.7-10 (Continued)

COMMON NAME	SCIENTIFIC NAME	I	IA	II	III	IV	V	VI	VII
Common Starling	*Sturnus vulgaris*			B	B	B	B	B	B
Solitary Vireo	*Vireo solitarius*					B	B	B	
Red-eyed Vireo	*Vireo olivaceus*					B	B	B	B
Philadelphia Vireo	*Vireo philadelphicus*						B	M	B
Warbling Vireo	*Vireo gilvus*					B	B	B	B
Black and White Warbler	*Mniotilta varis*					B	B	M	M
Tennessee Warbler	*Vermivora peregrinda*			V	B?	B	B	B	M
Orange-crowned Warbler	*Vermivora celata*		B	B	B	B	B	B	B
Yellow Warbler	*Dendroica petechia*	B?	B	B	B	B	B	B	B
Magnolia Warbler	*Dendroica magnolia*					B	B	M	M
Cape May Warbler	*Dendroica tigrina*					B	B	M	M
Yellow-rumped Warbler	*Dendroica coronata*		B	B	B	B	B	B	B
Townsends Warbler	*D. townsendi*							B	
Black-throated Green Warbler	*D. virens*						B	M	M
Bay-breasted Warbler	*Dendroica castenea*					B	B	M	M
Blackpoll Warbler	*Dendroica striata*		B	B	B	B	B	M	M
Palm Warbler	*Dendroica palmarum*				B?	B	B?	M	M
Ovenbird	*Seiurus aurocapillus*					B	B	B?	B
Northern Waterthrush	*Seiurus noveboracensis*		B	B	B	B	B	B	M
Connecticut Warbler	*Oporornis aqilis*						B	M	M
Mourning Warbler	*O. philadelphia*						B	M	M
Macqillivray's Warbler	*O. tolmiei*							B	B
Yellow-breasted Chat	*Icteria virens*								B
Common Yellowthroat	*Geothlypis tricnas*						B	B	B
Wilson's Warbler	*Wilsonia pusilla*		B	B	B	B	B	B	M
American Redstart	*Setophaga ruticilla*				V	B	B	B	B
House Sparrow	*Passer domesticus*					B	B	B	B
Bobolink	*Dolichonyx oryzivorus*							V	B
Western Meadowlark	*Sturnella neglecta*						B	B	B
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*						V	B?	B
Northern Oriole	*Icterus galbula*						B	B	B

Table 2.1.2.7-10 (Continued)

COMMON NAME	SCIENTIFIC NAME	I	IA	II	III	IV	V	VI	VII
Red-winged Blackbird	Agelaius phoeniceus			V	V	B	B	B	B
Rusty Blackbird	Euphagus carolinus	V	B	B	B	B	B	M	M
Brewer's Blackbird	Euphagus cyanocephalus					V	B	B	B
Common Grackle	Quiscalus quiscula					V	B	B	B
Brown-headed Cowbird	Molothrus ater					B	B	B	B
Western Tanager	Piranga ludoviciana					B	B	B	M
Rose-breasted Grosbeak	Pheucticus ludovicianus						B	B?	V
Blackheaded Grosbeak	P. melanocephalus							B	B
Indigo bunting	Passerina cyanea						V	B?	B
Lazuli bunting	P. amoena						V	B	B
Dickcissel	Spiza americana								V
Evening Grosbeak	Hesperiphona vespertina				V	V	B	B	V
Purple Finch	Carpodacus purpureus					V	B	B	M
Cassins Finch	C. cassinii							B	
House Finch	C. mexicanus							V	
Pine Grosbeak	Pinicola enucleator						V	B	V
Gray-Crowned Rosy Finch	Leucosticte tephrocotis			V			V	B	V
Hoary Redpoll	Acanthis hornemanni		B	B	M	M	V	B	V
Common Redpoll	Acanthis flammea	B	B	B	B	B	V	V	V
Pine Siskin	Spinus pinus			V	V?	B	B	B	B
American Goldfinch	S. tristis						B	B	B
Red Crossbill	Loxia curvirostra					B	B	B	B
White-winged Crossbill	Loxia leucoptera		B	B	B	B	B	B	
Rufus-sided Towhee	Papilo erythrophthalmus							B	B
Lark Bunting	Calamospiza melanocorys						V	B?	B
Savannah Sparrow	Passerculus sandwichensis	B	B	B	B	B	B	B	B
Grasshopper Sparrow	Ammodramus savamarum								V
Baird's Sparrow	A. bairdii							B?	B
Leconte's Sparrow	Ammospiza leconteii					B	B	M	M
Sharp-tailed Sparrow	Ammospiza caudacuta					B	B	M	M
Vesper Sparrow	Pooecetes gramineus					B	B	B	B
Lark Sparrow	Chondestes grammacus						B	V	V

Table 2.1.2.7-10 (Continued)

COMMON NAME	SCIENTIFIC NAME	I	IA	II	III	IV	V	VI	VII
Darkeyed Junco	*Junco hyemalis*		B	B	B	B	B	B	B
Tree Sparrow	*Spizella arborea*	B	B	B	B	M	M	V	V
Chipping Sparrow	*Spizella passerina*		V	V	B	B	B	B	B
Clay-colored Sparrow	*Spizella pallida*					B	B	B	B
Brewer's Sparrow	*Spizella breweri*							B	B
Harris' Sparrow	*Zonotrichia querula*			B	M	M	M	M	M
White-crowned Sparrow	*Zonotrichia leucophrys*	B	B	B	B	B	B	B	B
Golden-crowned Sparrow	*Z. atricapilla*						B	B	
White-throated Sparrow	*Zonotrichia albicollis*			V	V	B	B	M	M
Fox Sparrow	*Passerella iliaca*	V	B	B	B	B	B	B	M
Lincoln's Sparrow	*Melospiza lincolnii*		V	V	B	B	B	B	M
Swamp Sparrow	*Melospiza georgiana*					B	B	M	M
Song Sparrow	*Melospiza melodia*					B	B	B	B
McCowan's Longspur	*Rhynchophanes mccownii*							B?	B
Lapland Longspur	*Calcarius lapponicus*	B	B	B	M	M	M	M	V
Smith's Longspur	*Calcarius pictus*	B		B	M	M	M	M	M
Chestnut-collared Longspur	*Calcarius ornatus*						V	B	B
Snow Bunting	*Plectrophenax nivalis*	B		B	M	M	M	V	V

of passerine and upland birds. The aquatic sections east of the Arctic Red River contain essentially the same species in the same relative abundance as the Mackenzie Delta area.

Richards Island Supply Line

The proposed Richards Island Supply Line would pass through the Mackenzie Delta, crossing a maze of small streams and interconnected lakes. The alignment would be on moderate slopes along part of the proposed route and pass through upland forest habitat as well as aquatic and tundra vegetation complexes. The bird species along this proposed section are essentially the same as along the Prudhoe Bay Supply Line route.

Northern Mackenzie Segment of The Main Line

At a point almost due south of Travaillant Lake, the proposed route would enter the Mackenzie Valley and follow it for more than 500 miles. The northern Mackenzie segment is here considered to end at Norman Wells, 250 miles south of Travaillant Lake Junction.

This section of the proposed route would cross a variety of habitats. In some portions the alignment would be up to 20 miles from the river, whereas in other parts mountainous terrain or other physical barriers would bring it close to the river.

The proposed route would cross slopes and foothills ranging from moderate to very steep. The streams intersected vary in volume and intensity depending on slope and watershed. Most are not desirable waterfowl nesting habitat because they are subject to frequent flooding.

This section of the proposed route supports mainly forest-tundra vegetation on the uplands and low shrub-tundra at lower elevations. In some places the proposed alignment would be over numerous small interconnected lakes and meandering streams. Many large lakes would be encountered, but in some places water habitat is sparse or absent. The river environment is characterized by alluvial islands and sand bars and deltas at many tributary junctions.

The Mackenzie River valley is both a major waterfowl nesting complex and migration corridor. Tens of thousands of ducks, geese, swans, loons, mergansers, shorebirds, and sandhill cranes nest along the alluvial islands and sand bars. At least 148 species of 30 families have been reported as nesters, migrants or casual visitors in this section of the proposed route by Jacobson (1974).

Peregrine falcons, golden eagles, bald eagles, and ospreys nest along the entire Mackenzie River valley.

Southern Mackenzie Segment of the Main Line

The proposed route continues from Norman Wells along the east side of the Mackenzie River to a crossing of the River Between Two Mountains.

The islands around Norman Wells and south of Fort Norman are of particular importance for nesting and staging for both north and south migrations. The area between Great Bear River and Brackett Lake, the areas around Mackay Creek, and the Ramparts River are some of the most important waterfowl production areas along the Mackenzie River valley. Near Fort Simpson the proposed route crosses the Mackenzie River and leaves the Mackenzie River valley to pass southeasterly into Alberta. Here the proposed route crosses heavy mature stands of coniferous and mixedwood forests and the almost continuous maze of aquatic habitats of the valley is interspersed with upland slopes and large areas of muskeg and fens with numerous lakes and small streams.

Large numbers of waterfowl and shore birds migrate in a broad band through this area in both spring and autumn. The wetlands are not generally considered highly productive areas but may be an important reservoir of stable habitat during drought years on the prairie. Jacobson (1974) reports 199 species representing 38 families of birds in this section.

Bald eagles may nest in significant numbers in and around Trout Lake. Peregrine falcons and golden eagles also live in this portion of the proposed route.

Alberta Segment of the Main Line

The proposed route continues southeasterly through treed muskeg and forests of aspen and spruce and agricultural areas and existing gas fields. The Hay, Peace, Athabasca, Pembina and Saskatchewan Rivers are the major streams crossed by the proposed Main Line in Alberta. The Hay-Zama Lakes complex is an important waterfowl production and staging area with concentrations of geese reaching tens of thousands. This section of the proposed route also passes through scattered excellent nesting habitat for many species of ducks, grebes, mergansers, coots, loons and other waterbirds; nesting use by geese is extremely low. Buffleheads and goldeneyes nest in wooded areas around lakes and streams. Bistcho Lake is an important nesting area for bald eagles. The mixedwood forests north of the Hay River contain willow ptarmigan. Spruce, ruffed, and sharp-tailed grouse occur sporadically all along the route. Sharp-tailed grouse are most abundant in the agricultural and adjacent areas of aspen parklands along the Peace and Smoky Rivers, an area also inhabited by ring-necked pheasants and gray partridge. A great variety of songbirds breed in varying densities along the route.

Monchy Delivery Line

From Caroline Junction the delivery line to Monchy, Saskatchewan would cross aspen parkland, agricultural lands, and prairie, including sand hills and bushy uplands. This is good habitat for sharp-tailed grouse, ring-necked pheasants, and gray partridge. Prairie ponds along this route produce waterfowl and provide stopping places for large numbers during their north-south migrations. In the southeastern corner of Alberta sage grouse also occur. The Cypress Hills area is an island of lodgepole pine forest which provides a sanctuary for breeding birds (Table 2.1.2.7-10) not expected on prairies. Wild turkey is found in this area. The proposed route passes to the north of a Provincial park and lodgepole-pine forested area, which have some influence on the bird fauna. Raptors of the area include the prairie falcon, merlin, kestrel, Swainson's hawk, marsh hawk and the great horned and burrowing owls, the latter being of interest because it is outside the range of the prairie dog with which it is commonly associated.

Kingsgate Delivery Line

The Kingsgate Delivery Line would continue south from Caroline Junction for about 50 miles before swinging to the west and crossing the Rocky Mountains through Crowsnest Pass. This route includes habitat of upland game birds, sharp-tailed grouse, ruffed grouse, pheasants and gray partridge and ascends into the ranges of the spruce grouse, blue grouse and the white-tailed ptarmigan. Except for several duck species, including the harlequin duck which breeds on mountain streams, the region crossed by this proposed route appears to have a relatively small role in the production of waterfowl. Different habitats associated with elevation changes account for the presence of a variety of breeding bird species along this route (Table 2.1.2.7-10).

2.1.2.8 Ecological Considerations

The ecosystem provides the framework for analysis of the nature and functional relationships of balanced biotic and abiotic environmental complexes and for the synthesis of functionally related components into natural social units or communities. An ecosystem can occur at any scale, ranging from the total global biosphere and its interrelationships with the geosphere and atmosphere to that of a drop of water. In simplest terms, an ecosystem at any scale is an assemblage of organisms living in a state of balance with each other and with the abiotic environment, each species population satisfying its energy and material requirements, breeding conditions, and protection against environmental hazards. Solar energy is essential and is the sole external input to the system.

Each ecosystem exhibits an essential degree of uniformity in its biological composition, in the way it is organized and functions, and in the qualitative and quantitative nature of its abiotic environment. It incorporates all resident organisms as well as those that seasonally or regularly depend upon its resources. Each is an independent functional unit capable of sustaining all biological processes essential to the system, so long as the abiotic environment remains within limits of tolerance.

Every system has a degree of uniformity of characteristics which represent long-term development of a state of dynamic equilibrium between the physical and biological components. Within each of these systems, however, there is a great deal of variability in the kinds and distribution of plants and animals, and large differences in geology and the availability of minerals; altitude and topographic exposure to sun; water supply; heat distribution; age of surface; and other elements of environment. Through these variations there has developed a series of subsystems, hierarchies of ecosystems, that are individually different in significant ways, but related by sharing of certain properties. Lakes and streams are examples of subsystems within major terrestrial ecosystems.

The proposed route would cross all the major ecosystems from the Inner Continental Shelf Marine System of the Beaufort Sea; to freshwater lakes and streams; to the major terrestrial systems which begin to the north with the grassland of the Tundra, continue south across several forest-dominated systems, and end, in the case of the Monchy Delivery Line, in the Prairie Grassland Ecosystem of Saskatchewan.

Like all major ecosystems, the foregoing are under the control of climate, a fact made evident, for example, by the distribution of continuous permafrost, the tree line, and the treelessness of the Tundra. The Boreal Forest is predominantly coniferous forest; moose and numerous fur bearers are characteristic mammals. The Tundra is predominantly grassland; grazing mammals, such as caribou and lemmings, are typical.

The classification of ecosystems, their descriptions, the explanations of their processes, and the synthesis of component parts into total units have never been accomplished for the regions of interest and the intricate relationships forbid hasty interpretations of systems which at best are poorly known.

Landscape units provide the usual means of delineating ecosystems and vegetation as a dominant feature of the landscape often provides the ecosystem names, as in the case of Boreal Forest, or Herbaceous Coastal Tundra. Such a classification of ecosystems has been published for Alaska (Joint Federal-State Land Use Planning Commission for Alaska, 1973). Major ecosystems are mapped, as vegetation units in terrestrial cases, at a scale of 1:2,500,000. In addition to marine and freshwater ecosystems, there are land systems, including three tundra and six coniferous forest systems.

In the Alaskan system other biotic and abiotic components have been presented in descriptive, summarized form for each ecosystem as delineated by vegetation. This represents a first step toward a future integration and synthesis of Alaskan ecosystems.

The major Canadian ecosystems that would be affected by the proposed route are here defined in a modification of the Alaskan system. The geographic distribution and areas of ecosystems affected are discussed in Section 2.1.2.6 (Vegetation). Other ecological information pertinent to these systems occurs throughout Section 2.1.2.

Continental Shelf Ecosystem

Includes the marine environments of the shelf off the Yukon Territory and Mackenzie Delta, N.W.T. coasts of the Beaufort Sea.

Ice-affected Coast Ecosystem

Includes the arctic Beaufort Sea Coast of the Yukon and N.W.T.

Lake Ecosystem

Freshwater lakes and ponds throughout the proposed route.

Riverine Ecosystem

Streams of all watersheds throughout the proposed route. The Mackenzie River drainage system is a major example.

Tundra Ecosystem

Alpine Tundra Ecosystem--

Low Arctic Tundra Ecosystem--

1) Herbaceous Coastal Tundra Ecosystem

2) Low Shrub-Heath Ecosystem

Forest-Tundra Ecosystem

Boreal Forest Ecosystem

Parkland Ecosystem

Grassland Ecosystem

Only remnants remain and most of the original grassland area both in Alberta and Saskatchewan is productive farmland.

Subalpine Forest Ecosystem

Interior Wet Belt Forest Ecosystem

Ecosystem Productivity

Biological productivity in arctic marine and freshwater ecosystems is lower than in similar systems at lower latitudes. Both the rate at which energy is stored in photosynthesis or chemosynthesis, primary production, and rates of transfer through different trophic levels of the food web, in processes of secondary production, are lower as a consequence of kinds of organisms, low temperature and inadequacy of mineral nutrients, especially in the marine environment. The favorable season of summer, when temperatures are elevated, water is ice-free, and light is available for the photosynthetic process, is brief.

The rate of primary production is critical to the food supply of all organisms for the entire annual cycle. Primary production determines the potential amount of growth and reproduction of all organisms in the ecosystem, that is the total weight or volume of organisms, the biomass, per unit of the system. Low rates of primary production coupled with a short season of production results in low biomass in arctic waters.

Terrestrial ecosystems, such as Herbaceous Coastal Tundra, have been shown to have rates of primary production comparable to related vegetation at lower latitudes. Biomass production, however, which is rapid during the short summer season is retarded by the time factor, the brief period in which growth and reproduction can occur. Biomass, the standing crop of total biological populations, increases from the tundra grasslands, to low Shrub-Heath Tundra, to Forest-Tundra and reaches highest levels in the forests of the most favorable sites.

The most productive forests in the Forest-Tundra are the riparian spruce communities and in the Boreal Forest the upland forests of spruce, hardwoods and mixed woods.

Biomass production in forest systems decreases in rate after several decades and the forest becomes overage, or senescent. Cutting, forest fire or other disruptions result in rapid increases in production and greater diversity of the total plant and animal populations. Recurring fires in Forest-Tundra, Boreal Forest and Subalpine forests result in some of the most highly productive forests, the secondary communities of aspen, birch, pine and spruce.

The grasslands of the prairie provinces although now largely gone were highly productive ecosystems in their natural state. The same environment that produced high productivity in the natural communities now determines equal success in a thriving agricultural economy based largely upon cereal grasses.

Ecosystem Interrelationships

The flow of energy and materials through an ecosystem is illustrative of the complex interrelationships between organisms and the physical environment. These relationships, referred to in total as a food web, constitute a most important function of ecosystems at any scale. The food web includes primary producers, the green photosynthetic plants of the vegetation component, which convert visible wavelengths of solar energy, or light, into chemically bound energy. Primary consumers, grazing animals, or herbivores, consume green plants and derive their energy and nutritional needs from them. Herbivores are the prey of carnivores and through various levels of prey-predator relationships, the entire population of organisms derives its basic energy and nutrient requirement and each consumer, through its waste products, puts organic and inorganic materials back into the system for potential recycling. The death and accumulation of the remains of organisms not utilized, illustrated by peat deposits, tie up mineral nutrients and deprive the system of essential materials.

The recycling of these materials in a properly functioning system is partially accomplished by a host of organisms known collectively as decomposers which in terrestrial communities live largely unseen in the soils. These include bacteria, fungi and large numbers of soil arthropods, larvae and worms which, in obtaining their own food requirements from organic material, digest insoluble compounds and return soluble mineral materials to the system. Decomposers occur in large numbers and large total biomass even in the Arctic (Bliss and others, 1973). They are an essential component of the system and as important as the more conspicuous plants and animals, and equally require protection against environmental change.

Every ecosystem, whether on land, in the ocean, or in the freshwaters of lakes and streams, is dependent upon these food relationships. In aquatic environments, photosynthetic phytoplankton are at the base of the food chains and are consumed by zooplankton, certain fishes and other groups of animals which in turn are consumed by others until all are accommodated. Disruptions to any of the links of food use can be devastating to the system, especially if at the primary producer level upon which all consumers are dependent. Each system is in a state of balance and change in one component, whether natural to the system or induced by man, has far-reaching consequences to the total system.

As was alluded to in the discussion of vegetation, the patterns of distribution and the characteristics of individual ecosystems are the result of complex relationships between the available kinds of plants and animals and such environmental factors as climate, age of land surface, soil materials, relief of surface, permafrost and a host of other biotic and abiotic influences. The interrelationships between components in individual ecosystems are not well known nor are those between different ecosystems but rapid progress is being made.

The concept of the ecosystem gives direction to research which may in time permit a rational classification and understanding of natural units. For example, environmental research sponsored by the Applicant, as reflected by the Environmental Statement (CAGPL, 1974d,e) and its cited literature, was guided by the ecosystem concept, but the studies were on components, although in each case some interrelationships are discussed. The Environment Protection Board (1974b) research reports, also sponsored by the Applicant, are also organized around components.

The fact is, ecosystems are rather intractable objects of study. As stated by Bliss and others et al. (1973), "While the roots of the concept are much older, integrated studies of the trophic-dynamic interactions within and between components of an ecosystem have been conducted in detail only recently." Research needed on an integrated basis for all ecosystems is exemplified by the International Biological Program investigations of the Tundra Biome at Barrow, Alaska, Devon Island, Canada, and elsewhere. In an excellent treatment of arctic tundra ecosystems Bliss and others (1973) review early results of the IBP studies and state, "... a more detailed review of tundra ecosystems must await completion of the IBP studies." The results of these important investigations will be available in the near future.

The important consideration is not whether the functional interrelationships of ecosystems are currently understood, but rather, awareness that they exist. The disruption of the functions of a plant community, a lemming population, or a caribou herd are primary effects but the secondary and tertiary effects pulse through the entire ecosystems along all functional pathways of community interrelationships.

2.1.2.9 Economic Factors

The route of the proposed Arctic Gas Pipeline across Canada runs through the Yukon Territory, the Northwest Territories (N.W.T.) and the Provinces of Alberta, British Columbia, and Saskatchewan before entering the United States via Montana and Idaho. Most of the length of the pipeline within Canada lies within the N.W.T. and the Province of Alberta. The relatively short segments in British Columbia and Saskatchewan are sparsely populated and similar to the adjacent portions of Alberta.

History of Economic Development

Economic development of the northern Territories began in 1789 with the explorations of Alexander Mackenzie in the basin of the river that now bears his name. Fur trade began with the establishment of the first trading post at Lac Le Martre in 1789. Until then the Natives roamed in seminomadic groups looking for favorable areas for hunting and fishing. The caribou provided most of their food, clothing, and material for shelter and implements. After fur trade began, the Natives hunted non-food animals to obtain fur to trade for goods such as tea, sugar, flour, tobacco, etc. Soon the Natives became dependent upon these goods and the trade relationship.

The early development of Native-white trading took place in roughly four stages.

1) Indirect trading with Russians in Alaska through the eastern Alaska Natives. This ended about 1840 when Hudson's Bay Company established posts in the Mackenzie delta area.

2) Direct trading between Natives and whites in the region, at places such as Fort Good Hope, Arctic Red River, and Fort McPherson.

3) Trade in the north coastal region with American whalers, who needed a meat supply for their ships and who also hired Natives as whalers.

4) Reversion to fur trapping, especially white fox, after 1912 when whaling ceased in the Mackenzie area. When the demand for white fox and other furs dwindled in the 1930 depression era, the Natives' trapping economy suffered a severe setback.

The original Northwest Territory in 1670 included all the land between the Hudson Bay drainage (Rupert's Land) and the Crown Colony of British Columbia. This land, which included part of the prairie land south to the Canada-United States border, was deeded to Canada by Great Britain in 1870. This vast area was gradually reduced between 1870 and 1912 by the establishment of Manitoba, Saskatchewan and Alberta, which had agricultural economic bases, leaving the land north of 60° N latitude (presumably the northern limit of agriculture) with little economic potential other than fur trading, which was carried out largely in the Mackenzie basin.

Alberta, which was incorporated in 1905 as a Province, has passed from a fur trapping era to its present status as an urbanized manufacturing and mining economy. This was primarily accomplished by the railroad reaching Calgary in 1883 and the provision by the Federal Government for plentiful cheap and free land.

A new base for economic development was provided by the discovery of gold in what is now the Yukon Territory in 1896, and the subsequent discovery in Alberta of vast deposits of oil and coal.

Resources of economic significance ultimately were recognized in the Northwest Territories in 1920 with the drilling of the first oil well at Norman Wells and the building of a refinery at this site in the 1930's. Oil seepages had been reported here by Alexander Mackenzie in 1789. In the 1930's gold was discovered at Yellowknife and pitchblende at Port Radium. From then on, the economic dependence on fur was reduced; and an influx of white settlers and prospectors began. This created a demand for local supporting services, provision for which had traditionally lagged far behind demand.

World War I and the depression of the 1930's apparently delayed economic development of the Northwest Territories. During this period services in the critical needs, especially education, health, and welfare, were left largely in the hands of churches, the Royal Canadian Mounted Police (R.C.M.P.), fur traders, and Natives.

World War II did renew work and interest in the region, with construction of military outposts and highways. Post-war development along the roads, the construction of the Distant Early Warning (D.E.W.) line in the early 1950's, and the presence of Americans engaged in travel and exploration spurred the economy.

A wage economy has emerged in the N.W.T. since the late 1960's. Economic attractions have been enhanced by new and proposed roads, and by the extension of a railroad to Pine Point on Great Slave Lake. A program has been inaugurated by the government to foster a choice for the Natives between training to become part of the wage economy, or pursuing their traditional hunting-fishing-trapping way of life.

In response to rising demand and hopes from an expanding population for resource development, to the increased tempo of economic activity, and to local political awareness, the Territorial Government structure has been materially changed in the past two decades and particularly since 1967. The capital of the Northwest Territories was established at Yellowknife in the late 1960's. At present the Territorial Governments have legislative powers similar to Provincial legislatures except that all natural resources, except game, are the responsibility of the Federal Government.

The Territorial Governments have recently assumed the power to tax developments outside municipal boundaries, but to date only the Yukon Territory has exercised these powers. A basic handicap to activities of the Territorial Governments, however, is the lack of an adequate revenue base within their jurisdiction. Northwest Territories revenue sources are: license fees from the private business sector in a region of largely government business; fuel tax in a land of few vehicles and gasoline, in some communities, costing more than $1.00 per gallon; liquor tax; and tobacco tax.

It is difficult to make an accurate and detailed assessment of the past economic conditions and development in the northern Territories because relatively little economic (and social) information about the Mackenzie Valley and northern Yukon Territory has been published. In Alberta it is far easier to show the development from a nontrading system to a fur trading economy, to an economy based on mining, agriculture construction and manufacturing.

One difficulty in evaluating the economy of the Northwest Territories arose from the nonhomogeneity of this vast region. The northern Territories are in reality a series of miniregions, each with its own economic and other characteristics that are not amenable to generalizations. The economic entities vary from small tribal family groups that are largely dependent upon the resources of the land, to southern Canada-type urban centers largely dependent upon a relatively sophisticated economy.

The economy in Alberta has a long-term affinity with agriculture, mining, oil and gas development, tourism, and road, rail and air transportation. Although portions of Alberta are thinly populated and not highly developed in an industrial and urban sense, a wage economy and activity in the fields of oil and gas exploration and development, including pipelines, have been a part of the way of life for many years.

Principal Economic Activities

Rapid economic development is a current reality in the northern Territories, and data gathered as recently as two to four years ago may not be applicable today. In the past there have been no organizations that consistently and completely gathered economic data; nor is there currently a known established comprehensive effort in this field. The considerable data given by the Applicant have been collected in studies made since 1970, and compiled from other existing sources, and in large part are for the period since 1960.

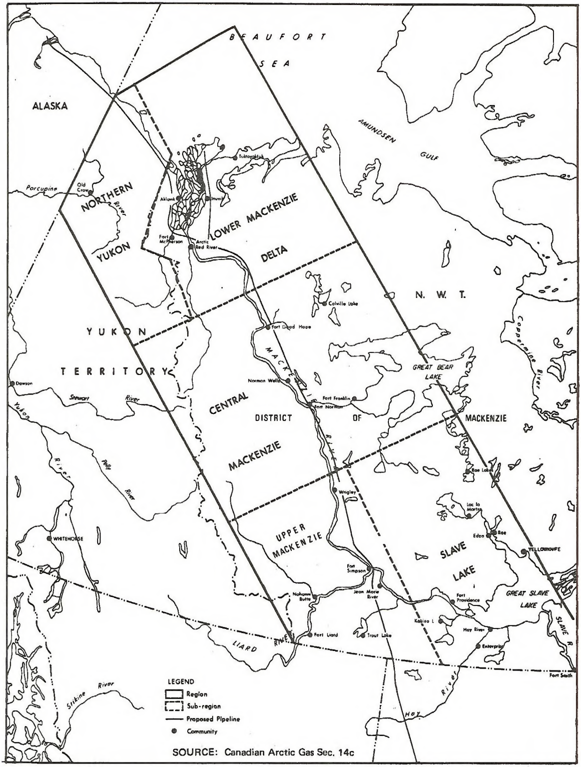
The current primary economic activities in the study region (Figure 2.1.2.9-1) of the northern Territories (Table 2.1.2.9-1) are fur trapping, subsistence hunting and fishing, commercial fishing, mining, oil and gas exploration and production, logging, and agriculture. The first five are significant in terms of either subsistence necessity, number of people involved, dollar value produced, or support of other economic activities, but none is important in all of these categories. Commercial fishing, mining, and oil and gas exploration and production are particularly of importance to only certain local areas. Logging and agriculture are of very minor economic significance and also restricted to relatively few areas; however, these activities fulfill a critical need in their restricted areas of application.

The secondary industries include: handicrafts and fur garments (the only export-oriented industry), baking, bottling, printing, and small manufacturing. There are only about 15 of these industries, all of which are small, and 9 of them are located in Yellowknife. These businesses are generally marginally profitable owing to limitations of markets, high transportation and operating costs, seasonality, unreliable supply systems, and lack of skilled management and staff.

In 1972, service industry activities provided employment for 75 percent of the estimated total of 6,343 man years of employment in the study region (Table 2.1.2.9-1). These activities include government, utilities, wholesale and retail trades, finance, insurance and real estate, community services, services to individuals and businesses, accommodations, food and tourist establishments, and construction contractors.

The transportation industry has grown in recent years along with the significant increase in goods and people entering the study region, particularly related to petroleum-industry activity. Over 30 trucking companies operate between Edmonton, Fort Simpson, Fort Smith, and Yellowknife (Figures 2.1.2.9-2 and 2.1.2.9-3). Major air carriers and some bush flying operators serve the region. Barge service is operated between Hay River and the coast during about 100 days in the summer months, and rail service extends from the Provinces as far north as Hay River and Pine Point.

In Alberta the current primary economic activities are mining, manufacturing, construction and agriculture. Forestry, trapping, fishing and electric power generation are secondary industries; combined, they only produce about 4% of Alberta's total net production, measured in dollars. Like the Northwest Territories, the majority of the labor force is employed in service industries.



SOURCE: Canadian Arctic Gas Sec. 14c

Figure 2.1.2.9-1 Study regions, sub-regions, and communities along the proposed route

Table 2.1.2.9-1 Study region employment, 1972

Source	Man-years of employment					
	Lower Mackenzie/ Delta	Central Mackenzie	Upper Mackenzie	Slave(a)	Yukon	Total(b)
Trapping, fishing	28	9	32	248	2	319
Oil, Gas, Mineral Industry	131	16	31	676	2	856
Manufacturing	0	0	0	5	0	5
Services						
--Government						
Federal	449	53	30	425	5	962
Territorial	278	46	91	702	7	1,124
Local	29	9	6	252	2	298
--Contracting	140	46	6	198	0	390
Transport	69	33	24	393	0	519
Other	234	106	120	1,066	4	1,530
Hire North	8	2	20	15	0	45
L.I.P./O.Y.P.	17	2	9	0	0	28
Casual	80	20	0	104	15	219
Unassigned	42	0	0	0	6	48
TOTAL	1,505	343	368	4,084	43	6,343

Note: (a) Excludes Fort Smith, Colville Lake and Rae Lakes.
(b) Includes male and female.

Source: Compiled from Gemini North survey data.

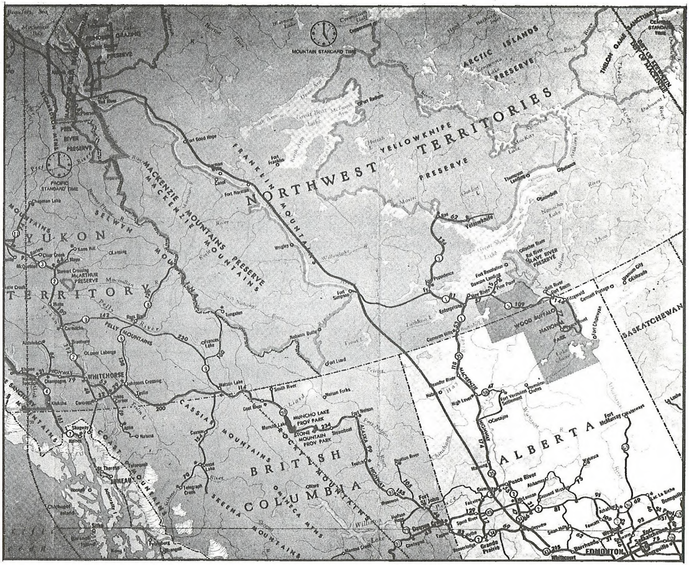


Figure 2.1.2.9-2 Highway map of Yukon Territory and Northwest Territories

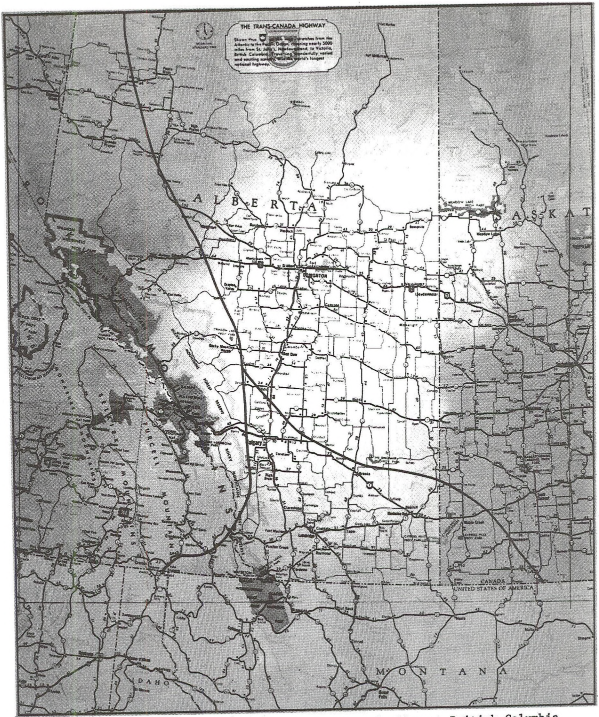

THE TRANS-CANADA HIGHWAY
Shown thus … stretches from the Atlantic to the Pacific Ocean, covering nearly 5000 miles from St. John's, Newfoundland, to Victoria, British Columbia. Traversing wonderfully varied and exciting scenery, … world's longest national highway.
ALBERTA
SASKAT
EDMONTON
Calgary
Lethbridge
Brooks
Medicine Hat
Red Deer
Lloydminster
Meadow Lake
MEADOW LAKE PROV. PARK
ROCKY
PURCELL
MOUNTAINS
CANADA
UNITED STATES OF AMERICA
MONTANA
IDAHO

Figure 2.1.2.9-3 Highway map of Alberta and parts of adjacent British Columbia and Saskatchewan

Economic Products

Furs traditionally have been one of the chief products of the northern region. The more important ones are muskrat, marten, beaver, mink, lynx, and white fox. Big game hunted for subsistence consists of caribou, moose, black bear, polar bear, and Dall sheep. Fish harvested for subsistence include whitefish, jackfish, trout, inconnu, pickerel, and salmon. Commercial fishing in Great Slave Lake produces whitefish and trout. Timber, chiefly spruce with very restricted distribution, provides a small yield of lumber for local use. Mining in and peripheral to the study region produces gold, silver, copper, lead, zinc, tungsten, cobalt and bismuth from six operations. Oil is produced at Norman Wells and crude is refined on a limited scale. Natural gas reserves are present, but the production is not known, except from Pointed Mountain, N.W.T. and Beaver River, Yukon. Native handicrafts and fur garments are apparently the only products fabricated by local residents from indigenous materials.

Alberta contains most of Canada's proven reserves of fossil fuels and accounts for over 25% of total Canadian mineral production. In 1971 Canadian mineral production was about $6.0 billion. Alberta accounted for about $1.65 billion, mostly in petroleum and coal. Besides petroleum and coal, other mineral and fuel resources include limestone, salt, phosphates, and bentonite, and vast quantities of natural gas. Major manufacturing industries are foods and beverages, petroleum and chemical products, metals, wood and paper. Major agricultural products are wheat, barley, hay and oats. Major forestry products are lumber, plywood and pulp.

Economic Markets

Under current and recent conditions a very small economic market exists in the Northwest Territories and Yukon Territory for the local economic products, except for oil from the Norman Wells field. Owing to the lack of primary and secondary industries based on local resource utilization in the Mackenzie Valley, there is little or no intersettlement exchange of goods and services.

Furs, fish, fur garments, and handicrafts are exported from the Mackenzie Valley to southern Canada and elsewhere. To a limited extent some market for these products exists within the northern Territories in the few urban centers, particularly those visited by tourists. Nonresident big-game hunters and sport fishermen provide a small market, limited by distance, cost, and accessibility, for trophy-type game animals and fish.

Because of its industrialized nature, products (mostly relatively unprocessed) from Alberta are exported all over the world, with major importers being the other areas of Canada, the United States, Japan, and the United Kingdom.

Employment and Income

The data that are available for employment and income are based largely on surveys made in 1972, and historical data that would provide comparative figures are lacking. Inasmuch as part-time employment is quite common, the reported data are given in terms of man years to properly reflect both part- and full-time employment. It is noted that a comparison of the 1972 employment total with the total

1972 working age population (converted to man-years) shows that actual employment accounted for about 45 percent of the man-years of employment that would be required to fully employ the working-age population. Although this is not a proper measure of employment, it is indicative of a high level of unemployment.

It is difficult to estimate the number in the male and female labor force who are currently unemployed but are seeking jobs, as there are only a few Manpower Centres for registering such persons. Contrary to what might be inferred from statistics which indicate that the full-time, year-around employment rate is fairly low, few persons may be unemployed and available for work during certain seasons owing in large part to hunting, fishing and trapping activities. Reliable data are not available for estimation of a seasonally adjusted employment rate. The number of man-years of employment relative to the size of the working age population in the region indicates (in the absence of fully definitive statistics) that either the participation rate is low, or there could be extensive underemployment and unemployment. The incidence of employment in the male working-age population is higher than that for the total male and female group.

The male working-age population seems to be under-utilized in terms of full-time employment. Furthermore, a major problem is the lack of job opportunities for women, who make up 45 percent of the working-age population. (Working age population is defined as male and female population between ages of 15 and 64. This is the maximum potential labor force.)

Principal Employers and Workforce Statistics

Along the proposed route in the Northwest Territories and Yukon sub-regions current employment is heavily dominated by the government sector, both Territorial and Federal, with additional employment generated largely within the local government and service industry sectors. Relatively little employment is generated by basic export industries such as mining, forestry, oil- and gas-related activities, and manufacturing. The distribution of man-years of employment is summarized in Table 2.1.2.9-1.

Major problems encountered in hiring northern personnel are absenteeism and alcoholism, according to a survey of 37 employers in the central and lower Mackenzie Delta regions. Other problems are: communication, high turnover, lack of skills, language, transportation, and lack of proper clothing or equipment.

The total working age (15-64 years) population in the Mackenzie and northern Yukon study region was 13,329 in 1971 (Table 2.1.2.9-2). This population is concentrated in the major communities of the Slave and Lower Mackenzie Delta subregions. Of this group, 7,554 are males, and they are also concentrated in the above subregions. It is believed that no significant changes in number or distribution have occurred since 1971.

A survey in 1972-73 indicates that the number of males who potentially would be available for work is relatively small, about 1,200, after deducting the number already employed from an effective labor force of about 2,800. This group of 1,200 is subject to reassessment on the basis of limitations of unemployables, hunting and trapping activities, seasonal employment patterns, amenability to wage

Table 2.1.2.9-2 Working age population by sub-region and community, 1971

(Population 15-64 years old)

Sub-Region/Community	
Lower Mackenzie/Delta	
Aklavik	295
Arctic Red River	55
Fort McPherson	423
Inuvik	1,792
Tuktoyaktuk	319
SUB-TOTAL	2,884
Central Mackenzie	
Fort Franklin	203
Fort Norman	140
Fort Good Hope	204
Colville Lake	33
Norman Wells	167
SUB-TOTAL	747
Upper Mackenzie	
Fort Liard	124
Fort Simpson	519
Jean Marie River	25
Nahanni Butte	35
Trout Lake	20
Wrigley	105
SUB-TOTAL	828
Slave	
Enterprise	30
Fort Providence	345
Fort Smith	1,333
Hay River	1,744
Kakisa	23
Lac La Martre, Rae Lakes	114
Rae/Edzo	510
Yellowknife	4,668
SUB-TOTAL	8,767
Northern Yukon	
Old Crow	103
SUB-TOTAL	103
TOTAL STUDY REGION	13,329

Source: Gemini North Ltd.

economy, wage rates, education levels, mobility patterns, nature, location and duration of jobs, and social pressures.

Income Characteristics

Income in this region may be divided into several categories, which, with some related terms, are defined as follows:

1) Real income--value of wage, salary, cash, and transfer payments in terms of current purchasing power plus the exchange value of income in kind and subsidies.

2) Cash income--compensation by money for goods sold or services rendered, as well as money transfers and allowances.

3) Kind income--exchange value of resources such as caribou or fish harvested and consumed, for which there is no actual monetary exchange.

4) Exchange value--market price, or its equivalent, for goods or services.

5) Subsidies--cash value of direct, indirect or imputed payments to people to assist in defraying living costs. Some government transfers are also a form of subsidy.

6) Transfer income--value of direct social assistance or welfare payments, old-age pensions, family allowances, disability pensions, unemployment insurance, etc., which are paid to individuals for which no services or work are performed or goods produced; synonymous with unearned income.

7) Personal income--gross wages and salaries, earnings from unincorporated business, self-employed earnings, and selected transfers from governments.

The data that have been gathered from field surveys and government sources for deriving income figures are not complete and are subject to interpretation. Accuracy of employer disclosures is indeterminate and coverage may be incomplete. Gross payrolls overstate employee income in many cases and are not identical to personal income. The market price or exchange value for kind income is highly sensitive to changes in local prices of substitute goods and other demand-supply relationships with respect to the resource being valued.

The estimated 1973 (survey by Gemini North, Ltd.) level of personal income in the study region indicates an average income of approximately $2,100 per capita. This includes wage, salary, self-employed, trapping, and transfer income, but does not include a dollar value for income in kind. A breakdown of this income by sub-region and community shows a range from maxima of $4,000 per capita in Enterprise and $3,280 in Yellowknife to minima of $250 in Rae Lakes and $268 in Trout Lake (Table 2.1.2.9-3). A similar survey in 1970 by Department of Indian Affairs and Northern Development (DIAND) that included the same region, except for Old Crow, shows an average per capita income of $1,195, with a range from $239 to $1,990 per capita (Table 2.1.2.9-4). The total indicated income for the study region was $22,906,474 in the 1970 DIAND survey, and $46,935,000 in the 1973 Gemini North survey. Either the earlier survey considerably

Table 2.1.2.9-3 Study region estimated income levels by community, 1973

Sub-Region/Community	Estimated 1973 Income	Per Capita Income
	($000)	($)
Lower Mackenzie/Delta		
Aklavik	690	941
Arctic Red River	116	1,221
Fort McPherson	660	793
Inuvik	7,845	2,340
Tuktoyaktuk	500	775
SUB-TOTAL	9,811	1,734
Central Mackenzie		
Colville Lake	47	671
Fort Franklin	270	736
Fort Good Hope	254	635
Fort Norman	320	1,143
Norman Wells	1,011	2,808
SUB-TOTAL	1,902	1,288
Upper Mackenzie		
Fort Liard	188	667
Fort Simpson	1,936	1,508
Jean Marie River	55	887
Nahanni Butte	60	909
Trout Lake	15	268
Wrigley	141	783
SUB-TOTAL	2,395	1,241
Slave		
Enterprise	200	4,000
Fort Providence	484	762
Hay River	6,513	1,974
Kakisa Lake	25	543
Lac La Martre	64	366
Rae Lakes	20	250
Rae/Edzo	780	537
Yellowknife	24,601	3,280
SUB-TOTAL	32,687	2,469
Northern Yukon		
Old Crow	140	648
SUB-TOTAL	140	648
TOTAL STUDY REGION	$46,935	$2,084

Source: Compiled by Gemini North Ltd. from D.I.A.N.D. 1970 Manpower Survey data and 1972/73 Gemini North Ltd. field surveys.

Table 2.1.2.9-4 Study region personal income from all sources, 1970

	D.I.A.N.D. Estimated Income	Per Capita Income[1]
Lower Mackenzie/Delta		
Aklavik	$ 536,971	$ 826
Arctic Red River	102,529	1,139
Fort McPherson	423,655	504
Inuvik	3,197,317	1,184
Tuktoyaktuk	339,451	573
SUB-TOTAL	$ 4,599,923	$ 944
Central Mackenzie		
Colville Lake	$ 26,917	$ 385
Fort Good Hope	189,820	542
Fort Franklin	253,868	846
Fort Norman	260,331	868
Norman Wells	293,378	1,012
SUB-TOTAL	$ 1,024,314	$ 782
Upper Mackenzie		
Fort Liard	$ 145,426	$ 559
Fort Simpson	463,721	618
Jean Marie River	11,967	239
Nahanni Butte	16,528	262
Trout Lake	12,172	304
Wrigley	92,708	530
SUB-TOTAL	$ 742,552	$ 555
Slave		
Enterprise	$ 53,276	$1,066
Fort Providence	152,484	277
Hay River	2,696,157	899
Kakisa Lake	18,694	415
Lac La Martre	63,840	376
Rae Lakes	27,269	682
Rae	327,918	285
Snare Lakes	6,151	615
Yellowknife Area	13,193,896	1,990
SUB-TOTAL	$16,539,685	$1,420
STUDY REGION TOTAL[2]	$22,906,474	$1,195

[1] Population estimates from Department of Local Government, Government of the N.W.T. and Gemini North Ltd. estimates.

[2] Excludes Old Crow, Fort Smith.

Source: D.I.A.N.D. Manpower Survey, Oct. 1, 1969-Sept. 30, 1970. Table 67.

underestimated income levels, or income levels actually rose substantially during that 3-year period.

The per-capita earnings of Native groups are below national poverty levels, and non-native residents earn more per capita than Canadians south of 60° N latitude. There is a wide disparity in incomes earned by the various ethnic groups, and all Native groups have relatively little cash income. It should also be noted that living costs in northern Canada are significantly higher than in southern Canada, and this must be taken into account in assessing real income differentials.

The importance of income in kind, which is not included in the foregoing figures, should not be understated. If the wildlife resources that are consumed are valued at costs of alternative store foods, the value of such foods would exceed $1,500,000.

Sources of cash income, as determined by the DIAND survey in 1970, are given in Table 2.1.2.9-5. Wages and salaries from all sources account for approximately 90 percent of the total, and about 5 percent is derived from various governemnt assistance payments (transfer payments). The Gemini North survey in 1973 shows that government wages and salaries alone amounted to $20,701,000 or 44 percent of total income, and transfer income was estimated to be $2,400,000 or 6.3 percent of income from all sources.

Local Tax Structure and Base Characteristics

As previously mentioned, the lack of a viable tax base is a severe handicap to Territorial Government, and the Federal Government still retains the rights to revenues from natural resources except game. The Territorial Governments now are authorized to tax developments outside of municipal boundaries, but only in Yukon Territory has this power been used. Six local levels of government have been established, based largely on size, and four of these have revenue-raising authority. In most cases the revenue base is very limited.

Principal Sources of Tax Income

Apparently the Territorial Government obtains tax revenues from business licenses, fuel, liquor, tobacco, and a general sales tax. Figures given for 1971-72 in the Gemini North report show that revenue collected within the Northwest Territories was $16,047,088 or 20.83 percent of the total operating revenue. The sources from which this is derived are not given. Revenue from Federal Government sources makes up the remaining 79.17 percent.

The local subdivisions and their revenue-raising functions are:

1) City--population exceeding 6,000 and taxable land assessment of $2,500 per capita; revenues from community service charge, property tax fines, fees, licenses, permits.

2) Town--population exceeding 1,000 and taxable land assessment of $2,500 per capita; revenues from same sources as city.

3) Village--population of 500 and raising or about to raise revenue by land taxes; revenues from same source as a city.

Table 2.1.2.9-5 Sources of income by sub-region, 1970

	Wages/Salaries	Self Employment	Trapping	Transfer Payments[1]	Total
Lower Mackenzie/Delta	$ 4,120,028(89.6)[2]	$128,413(2.8)	$ 72,460(1.6)	$ 279,022(6.0)	$ 4,599,923(100)
Central Mackenzie	860,820(84.0)	7,625(.7)	27,315(2.7)	128,554(12.6)	1,024,314(100)
Upper Mackenzie	604,642(81.4)	8,320(1.1)	36,467(5.0)	93,093(12.5)	742,522(100)
Slave	14,977,123(90.6)	824,647(5.0)	68,305(.4)	669,610(4.0)	16,539,685(100)
TOTAL	$20,562,613(89.8)	$969,005(4.2)	$204,547(.9)	$1,170,279(5.1)	$22,906,444(100)

[1] Aggregation of family allowances, pensions and income from other government sources (welfare payments or social assistance).

[2] Bracketed figures indicate percent of total sub-regional income attributable to source.

Source: Compiled by Gemini North Ltd. from D.I.A.N.D., 1970 Manpower Survey.

4) Hamlet--established by petition of 25 residents and with Commissioner's approval; revenues from community service charge, permits, licenses, fees, and fines.

5) Settlement--not incorporated, but with a council formed; no revenue-raising sources.

6) Unorganized--not incorporated and no council; no revenue-raising sources.

Only nine communities qualify for revenue-raising status: Yellowknife (city); Inuvik, Fort Smith, Hay River (towns); Fort Simpson (village); Akalavik, Tuktoyaktuk, Fort Franklin, Rae-Edzo (hamlets).

In 1973 only residents of the larger population centers paid municipal taxes. Residents of the smaller communities did not, even though they operated some commercial enterprises. An exception is Norman Wells, a settlement, where residents and private businesses first paid municipal taxes in 1972. One difficulty in imposing municipal taxes in smaller settlements is the risk of displacing Native residents from their homes because of the tax cost involved.

In Yellowknife, Inuvik, and Fort Simpson building assessments are based on 66.6 percent of the 1963 replacement cost calculated for Edmonton. Serviced land is generally sold by the municipality to a purchaser at a price that recovers the cost of development and services. It is then assessed at a current market value which is usually greater than the original purchase price.

Examples of tax rates for land and a 3-bedroon, no basement home of about 1,000 square feet are shown in Table 2.1.2.9-6. Taxes ranged from nil to $811 in 1972. The school tax rate on assessed value in most communities is 15 mills, but is 23 mills in Yellowknife.

Distribution of Revenues for Public Services

The operating and capital expenditures of the Northwest Territories Government from 1969 to 1972 are summarized in Table 2.1.2.9-7. The increase in total expenditures from $41,279,318 in 1969-70 to $90,957,473 in 1971-72 is notable, and a more dramatic comparison can be made with the total of $2,746,840 that was expended in 1959-60. Much more is expended than is collected within the territory in 1971-72, or about 20.8 percent of the total operating revenues.

No details are given for the distribution made of revenue funds collected by the communities. However, the uses of local revenue funds range from garbage and sewage collection and water delivery in the smaller settlements to financing of bond issues for major capital improvements such as roads and utilities in the larger towns and cities.

Economic Trends Without the Proposed Project

A strong trend toward economic development of the northern region, and particularly the study region, is already underway, and has been stimulated in large part by the oil and gas exploration activities in recent years.

Table 2.1.2.9-6 Municipal taxes and assessments on a typical three-bedroom house, selected communities, 1972

	Building[1]	Land[2]	Total	Mill Rate	Taxes/ year	Taxes/ month
Inuvik	$6,300	$2,230	$8,530	42.00	$358	$29.83
Fort McPherson	nil	nil	nil	nil	nil	nil
Norman Wells	6,300	100	6,400	31.00	198	16.50
Fort Simpson	6,300	1,200	7,500	42.38	318	26.50
Yellowknife	6,300	6,570	12,870	63.00	811	67.58
Hay River	6,300	1,320	7,620	41.00	312	26.00
Fort Smith	6,300	1,000	7,300	55.00	402	33.50
Pine Point	6,300	2,150	8,450	59.69	504	42.00

[1] Without basement - 3 bedroom house, 1,000 sq.ft.

[2] With complete services where available - normal lot size for community.

Source: Compiled by Gemini North Ltd. from Government of the N.W.T. Assessment Data and Mill Rates.

Table 2.1.2.9-7 Government of the Northwest Territories operation and capital expenditures, 1969-1972

Expenditure	1969-1970	% of Total	1970-1971	% of Total	1971-1972	% of Total
Operation and Maintenance						
Education	$ 7,465,328	21.79	$13,363,609	22.92	$16,114,615	23.16
Public Works	7,459,114	21.77	15,563,764	26.70	15,465,702	22.23
Administration	5,204,815	15.19	7,766,031	13.32	8,781,694	12.62
Health	3,350,167	9.78	3,891,588	6.68	5,939,082	8.54
Social Development	3,159,420	9.22	4,848,947	8.32	5,783,282	8.31
Local Government	2,560,283	7.47	4,760,908	8.17	5,275,171	7.58
Industry and Development	1,971,868	5.76	3,598,124	6.17	4,221,244	6.07
Territorial Treasurer	721,110	2.11	1,270,491	2.18	3,891,217	5.59
Territorial Secretary	1,119,143	3.27	1,557,169	2.67	1,997,839	2.87
Centennial	225,048	0.66	364,822	0.63	-	-
Interest on Loans From Government of Canada	1,020,523	2.98	1,312,910	2.25	2,105,650	3.03
SUB-TOTAL	$34,256,819	100.00	$58,298,363	100.00	$69,575,496	100.00
Project Capital	7,022,499		13,939,101		21,381,977	
TOTAL	$41,279,318		$72,237,464		$90,957,473	

Employment in the region is predominantly in the government-service field. Other service industries, and primary industries such as mining, oil and gas exploration and development, and forestry also offer significant sources of jobs. There is no firm basis for making a quantitative projection to 1985 of the regional employment situation, but it is conceivable that a shifting age structure in the labor force and a trend to wage employment on the part of young people may lead to increased competition for available jobs and probably a deterioration of an unemployment situation that is already unsatisfactory.

A projection of income levels to 1985 requires too many unknown factors to be attempted realistically. No estimates of projected income, in the absence of the pipeline, are presented by the Applicant. Presumably a trend similar to that in the past few years would continue, but allowances would have to be made for more rapid changes in the technologic, economic, social, cultural, and political fields that could have both beneficial and detrimental effects.

Economic activity in the trapping, hunting, and fishing pursuits is likely to remain roughly the same as during the past few years. Several countercurrents that affect this traditional life style are developing and render future projections uncertain. On one hand there has been a strong trend toward a wage economy, for some the rigors of trapping and subsistence hunting are becoming less attractive, and the future prices and demand for furs is uncertain; on the other hand there is an increasing tendency for residents to pursue these activities for other than income, to adhere to their cultural heritage, and for some it will remain a necessity to avoid starvation or dependence on social assistance programs.

No significant increases in the level of activity and economic return from agriculture, forestry, commercial fishing, mining, and oil and gas development are foreseen in the period through 1985 if the proposed pipeline is not built. Probably current levels of oil and gas development would decline in the absence of a pipeline and cause decreases in other closely-related activities.

It is anticipated that, in the absence of major new development, existing secondary industry will increase its contribution to employment and income in proportion to the increase in population. It also seems reasonable to project an expansion of the service sector in direct relationship to population and limitations of the size of market. An accelerated growth of Federal Government service personnel may outpace expansion of other services owing to pressure for introduction of new public services and facilities. Also, tourism may be expected to expand more rapidly than many other activities in the next 10 years.

It is difficult to predict the net change in transportation activities in the absence of the pipeline. The normal increase in population might be expected to yield a corresponding increase in demand for transport services, and commitments to improvement of facilities and service have been made. However, any decline in oil and gas exploration activity would significantly reduce transport traffic. It is unlikely that transportation offers significant opportunities for increased employment, and it is probable that some decline, at least at some periods, can be expected.

It appears that no significantly large advances or declines in many phases of the economy in the region north of 60° N latitude can be expected through 1985 in the absence of the pipeline or some similar activity. However, without a pipeline for transport of gas to markets, petroleum exploration would probably be cut down or curtailed with a resulting negative impact on the economy. No data are presented for the region south of 60° N latitude, but presumably the economy is relatively stable and subject to many economic factors that are of equal or greater import than the pipeline.

2.1.2.10 Sociological Factors

Population

Northwest Territories

History of Area Population Growth

The population of the entire Northwest Territories has increased from 6,507 in 1911 to 34,805 in 1971. The average annual percentage increase has exceeded that for all of Canada throughout this time with the exception of the period 1921-1931 (Table 2.1.2.10-1). The rate of natural increase (total births minus total deaths, and excluding net migration, however, has shown a reasonably constant decline for the period 1961 to 1972. This is attributed to a declining birthrate and a fairly constant death rate.

The introduction of fur trade to the northwestern region after 1789 resulted in irreversible changes in the size and distribution of the population, largely due to the introduction of diseases. For example, the Chipewyan group was reduced to about 10 percent of its precontact number by smallpox. Some groups became extinct, and many remnant groups recombined and moved. The development of fur trading centers, missions, and schools resulted, to various degrees, in new concentrations of Native groups.

Current Population

The estimated population within the study region in 1971 was 23,662, which is about 68 percent of the 34,805 reported for the entire Northwest Territories. The distribution of the 23,662 persons by sub-regions and communities in 1971 is shown in Table 2.1.2.10-2. Approximately 63 percent of the total population is in the Slave Sub-region, with Yellowknife accounting for nearly half of this number. The Lower Mackenzie-Delta Sub-region includes another 23 percent, owing in large part to the concentration of people in Inuvik. The extent to which the trend to an urban society has progressed is shown by the presence of 72 percent of the population in the towns of Inuvik, Fort Smith, Hay River, Fort Simpson, and Yellowknife. The other 28 percent is distributed among 21 other communities.

Ethnic Breakdown

Estimated figures show that 7 percent of the 23,662 are Inuit (Eskimo), 26 percent are Treaty Indians (those registered on a recognized list), and 67 percent are listed as "Other". The "Other" group includes Non-Treaty Indians, Metis (those of mixed Native and white ancestry), and white people. The distinctions between the various ethnic groups are difficult to draw accurately, and are further blurred by some individuals' choice of group.

Table 2.1.2.10-1 Population growth 1911-1971--Northwest Territories and Canada

	NORTHWEST TERRITORIES			CANADA	
Year	Total Population	Average Annual Percentage Increase Over Period	Percentage of Canada's Total Population	Total Population	Average Annual Percentage Increase Over Period
		%			%
1911	6,507		.09	7,206,643	
1921	8,143	2.3	.09	8,787,949	2.0
1931	9,316	1.3	.09	10,376,786	1.6
1941	12,028	2.6	.11	11,506,655	1.0
1951	16,004	3.0	.11	14,009,429	2.0
1956	19,313	3.4	.12	16,080,741	1.3
1961	22,998	3.2	.13	18,238,247	2.2
1966	28,738	4.2	.14	20,014,880	1.6
1971	34,805	3.5	.16	21,568,310	1.3

Source: Statistics Canada, 1971 Census of Canada, Volume 1, Part 2, 1973; Dominion Bureau of Statistics, 1966 Census of Canada, 1967 and 1961 Census of Canada, 1963.

Table 2.1.2.10-2 Estimated 1971 population by sub-region and community

Sub-Region/Community	
Lower Mackenzie/Delta	
Aklavik	660
Arctic Red River	95
Fort McPherson	841
Inuvik	3,249
Tuktoyaktuk	627
SUB-TOTAL	5,472
Central Mackenzie	
Colville Lake	67
Fort Franklin	434
Fort Good Hope	375
Fort Norman	260
Norman Wells	363
SUB-TOTAL	1,499
Upper Mackenzie	
Fort Liard	252
Fort Simpson	1,004
Jean Marie River	50
Nahanni Butte	65
Trout Lake	40
Wrigley	191
SUB-TOTAL	1,602
Slave	
Enterprise	55
Fort Providence	647
Fort Smith	2,490
Hay River	3,004
Kakisa Lake	44
Lac la Martre	172
Rae/Edzo	1,171
Rae Lakes	66
Yellowknife	7,224
SUB-TOTAL	14,873
Northern Yukon	
Old Crow	216
TOTAL STUDY REGION	23,662

Source: Compiled by Gemini North Ltd.

There are six Indian groups represented in the study region, the Chipewyan, Yellowknife, Dogrib, Slave, Hare, and Loucheux; and one Eskimo group, the Inuit. In addition there are five ethnic-interest groups, based on both ethnic origin and legal status of the individuals, that have been organized in 1968 or later. These are:

1) Indian Brotherhood of the Northwest Territories which represents some 7,000 Treaty Indians who are defined as persons registered on band lists in areas covered by Treaties 8 and 11.

2) Metis Association of the Northwest Territories, which represents about 7,000 people of mixed blood.

3) Yukon Native Brotherhood, which represents some 3,000 registered Indians in the Territory who are members of 12 basic Indian communities.

4) Yukon Association of Non-Status Indians, which represents 3,500 to 5,000 non-registered Indians, or people of mixed ethnic background in the Yukon Territory. Another source estimates that only about 1,500 may be represented.

5) Inuit Tapirisat of Canada, which represents some 17,000 Inuit not all of whom are members. This organization is represented in Inuvik, Tuktoyaktuk and Aklavik by the Committee for Original Peoples Entitlement.

Provinces

The opening of farmlands to settlement provided the main impetus to Alberta during the early years of its history. The best agricultural land was settled during the years just prior to World War I. During the depression years immigration virtually ceased. With the end of World War II another large immigration occurred, this time industrial workers who settled in the cities (Table 2.1.2.10-3 and Table 2.1.2.10-4)

There are a little more than 30,000 Indians in Alberta, grouped into 41 bands. Most of the Indians, about 23,000, live on Indian reserves provided by the Government. The Indians constitute less than 2% of the over 1.6 million population of Alberta.

Before World War II the economy of Alberta was predominantly agricultural. Most of the population lived in rural areas and was engaged in agricultural pursuits. Since the war urbanization has been rapid. About two-thirds of the population now live in large towns and cities, and only about one quarter of the population live in rural areas (Table 2.1.2.10-3 and Table 2.1.2.10-4)

Alberta is divided into 15 census divisions (Figure 2.1.2.10-1). A good measure of increasing urbanization is that Census Division 6 which includes Calgary, almost doubled its population between 1956 and 1971, while increasing its percentage of Provincial population from 21.2% to 27.5% (Table 2.1.2.10-5).

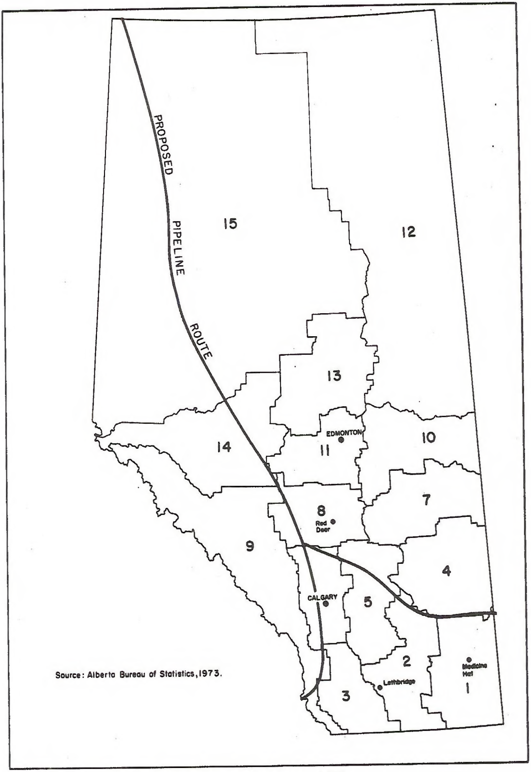
Some of the Indians in Alberta have entered professions, trades, and agricultural pursuits, and have fitted into the economy of the area in which they live. Others are mostly dependent on hunting, fishing and trapping. Opening of remote areas because of mining

Table 2.1.2.10-3 Population growth and distribution, Alberta

Year	Population	Distribution (%)	
		Urban	Rural
1911	374,295	29.4	70.6
1921	588,454	30.1	69.9
1931	731,605	31.1	68.9
1941	796,169	31.5	68.5
1951	939,501	45.8	54.2
1961	1,331,944	63.9	36.1
1971	1,628,000	73.5	26.5

Table 2.1.2.10-4 Large centers of population in Alberta

	1951	1961	1971
Edmonton	176,782	337,568	438,152
Calgary	142,315	279,062	403,319
Lethbridge	22,947	35,454	41,217
Red Deer	7,575	19,612	27,674
Medicine Hat	16,364	24,484	26,518
Grande Prairie	2,664	8,352	13,079



Source: Alberta Bureau of Statistics, 1973.

Figure 2.1.2.10-1 Alberta Census Divisions, 1972

Table 2.1.2.10-5 Area and density of population census divisions, Alberta, 1956, 1961, 1966, and 1971

Census Division	Population No.	1956 % of Total	Density No.	Population No.	1961 % of Total	Density No.	Population No.	1966 % of Total	Density No.	Land Area in Square Miles	Population No.	1971 % of Total	Density No.
1	34,496	3.1	4.27	39,140	2.9	4.84	38,858	2.7	4.81	7,928	39,149	2.4	4.94
2	74,991	6.7	10.73	83,306	6.3	11.92	82,719	5.7	11.83	6,573	86,624	5.3	12.83
3	30,426	2.7	6.35	30,967	2.3	6.46	29,592	2.0	6.17	4,740	30,940	1.9	6.53
5	38,120	3.4	5.89	38,115	2.9	5.89	35,987	2.5	5.56	6,453	34,485	2.1	5.34
6	237,886	21.2	48.10	317,989	23.9	64.29	369,140	25.2	74.63	4,816	447,079	27.5	92.83
8	64,168	5.7	11.35	76,533	5.7	13.53	83,912	5.7	14.84	5,819	85,638	5.3	14.72
9	17,239	1.5	0.97	20,274	1.5	1.14	18,195	1.2	1.02	17,320	19,781	1.2	1.14
14	15,846	1.4	1.32	19,282	1.4	1.16	20,358	1.4	1.70	12,399	21,665	1.3	1.75
15	70,417	6.3	0.76	76,884	5.8	0.83	88,344	6.0	0.95	90,478	94,762	5.8	1.05

NOTE: There are small changes in division areas from census to census.
SOURCE: Alberta Bureau of Statistics.

activities and railroads is expected to improve the economic conditions of Indians and Metis in the area.

As of 1970 the population of British Columbia was 2,137,000, of which only 39,700 inhabitants occupied the East Kootenay District. This is the slowest growing (2 percent per year) region in the Province, with the Fernie-Cranbrook-Kimberley area accounting for most of the growth.

The area along the route in southwestern Saskatchewan is sparsely settled. The approximate population distribution is shown in Figure 2.1.2.10-2.

Community Structure

There is no prototype community along the proposed route through the Mackenzie Valley and northern Yukon Territory. The 26 communities in and near the study region north of 60° N latitude range from small communal groups of one or more families to relatively modern urban centers. Each community is unique, relatively insular, and mainly absorbed with its own interests.

Many of the residents perceive their communities to be the settlement itself plus all adjacent lands normally used by them for fishing, hunting, and trapping, rather than limited by the prescribed legal boundaries. Many Native residents in the N.W.T. consider their community to be the place where they are recorded on the band list, though they may not have resided there for years. As a result of these factors, there may be large fluctuations of both listed and actual populations in various communities.

Local Government

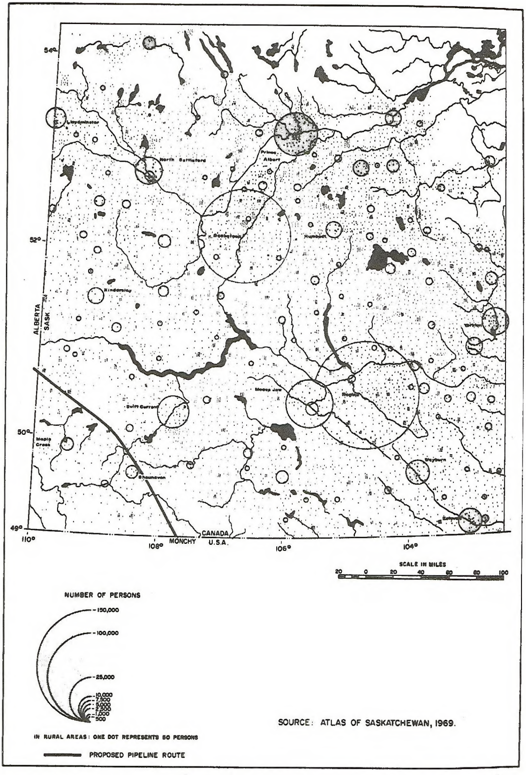
Northwest Territories

There are six formal categories of local government. Their description and the number within the Northwest Territories is below:

1) Unorganized. Not incorporated, no Council, budget, revenue or employees. No voice or anyone to act for it. There are nine unorganized areas within the study portion of the Northwest Territories. (Arctic Red River, Colville Lake, Jean Marie River, Old Crow, Fort Liard, Trout Lake, Rae Lakes, Kakisa Lake, Lac La Martre, Enterprise (Figure 2.1.2.10-3).

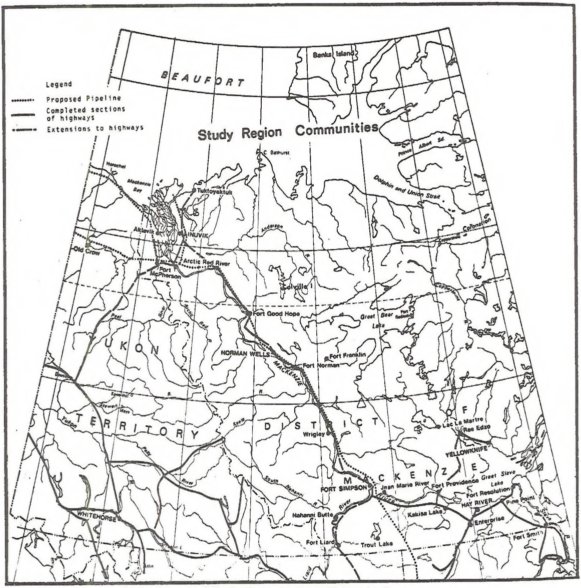
2) Settlement. Not incorporated, has a Council of 6-8 persons with one elected as Chairman. Budget is by region with guidelines from the Settlement. There are no revenue sources, no regular employees, and capital projects are funded and carried out by the Territorial Government. The Council can only advise and submit resolutions to the Territorial Government, but controls its per capita grant for community projects. There are eight settlements within the study portion of the Northwest Territories (Norman Wells, Fort Providence, Fort McPherson, Fort Good Hope, Fort Norman, Nahanni Butte, Lac La Martre, Wrigley; (Figure 2.1.2.10-3).

3) Hamlet. It is incorporated by petition of 25 residents and Territorial Commissioner's approval. The Council has 8 members, from whom one is elected as Chairman, and this body sets the budget with



SOURCE: ATLAS OF SASKATCHEWAN, 1969.

Figure 2.1.2.10-2 Southwestern Saskatchewan population distribution, 1966



Source: "MacKenzie Valley Pipeline Assessment," Pipeline Application Group, Ministry of Indian Affairs and Northern Development.

Figure 2.1.2.10-3 Location map of communities in Yukon Territory and Northwest Territories

guidelines from the Territorial Government. It obtains revenues from several local sources, and has its own employees in accordance with budget. It can establish ordinances and control municipal services, safety, health, and other relevant local matters. Capital projects are carried on by the Territorial Government. There are four hamlets within the study portion of the Northwest Territories. (Aklavik, Fort Franklin, Rae-Edzo, and Tuktoyaktuk; Figure 2.1.2.10-3).

4) Village. Distinguished by having a population of at least 500, and raising or about to raise revenue by land taxes. It has a Council of 8 with a Chairman, that sets the budget in consultation with the Territorial Government. It raises revenues, has employees, can finance by means of debenture borrowing, can buy and sell property, and can receive matching grants of 50 percent for roads and sidewalks. There is one village (Fort Simpson) within the study portion of the Northwest Territories (Figure 2.1.2.10-3).

5) Town. Distinguished by a population of at least 1,000 and by having a taxable land assessment of $2,500 per capita. It is governed by a Mayor and 9 councilors, who set the budget, raise revenue from local taxes and fees, and hire employees. It can finance capital projects and receive matching grants, similar to a Village. There are three towns within the study portion of the Northwest Territories. (Inuvik, Hay River, Fort Smith; Figure 2.1.2.10-3).

6) City. Distinguished by a population of at least 6,000 and a taxable land assessment of $2,500 per capita. It is governed by a Mayor and 8 Aldermen who have the same authority as the Town Mayor and Council. Towns and Cities have a few extra areas of responsibility over Villages, but have greater authority to act without Territorial approval. There is one City (Yellowknife) within the study portion of the Northwest Territories (Figure 2.1.2.10-3).

Alberta

Municipal administration takes a variety of forms in Alberta. There are Cities, Towns, Villages, Hamlets, Counties, Municipal Districts, Improvement Districts, and special areas. Mayors, Councils, and school and hospital boards are elected. The major sources of municipal revenue are the property tax, the local improvement tax, and the business tax. Large grants are made to the Governmental entities by the Provincial Government. However, some municipalities derive additional revenues from the operation of utilities.

Housing Characteristics

Northwest Territories

Adequate housing, in terms of both quantity and quality, has been pointed out as a current problem and would continue to be a problem, with or without construction of the proposed pipeline, unless steps are taken to improve the situation. There were about 5,100 dwelling units in the study region in 1973, and there was a need for 660 to 1,719 additional units depending upon whether 4 or 3 residents per unit are assumed (compared with the 1966 Canadian average of 3.7 per unit).

An additional 3,500 dwelling units will be required by 1983 without the proposed pipeline development, assuming a population increase of 11,495 between 1972 and 1983. In 1971 a government survey that did not include a number of smaller, predominantly Native, communities, estimated that 52% of N.W.T. housing was fair or poor.

The quality and kind of houses range from shacks, and some tents, to modern subdivision houses and apartments. In some areas mobile-home units are used.

Most of the housing is government owned and subsidized. The types of ownership of existing housing are shown in Table 2.1.2.10-6. It is significant to note that in the Northwest Territories only 7 percent of the housing is occupant owned and non-rental, compared with a Canadian average in 1966 of 63 percent. Inflation has put new-shelter costs beyond the economic reach of most northerners who do not receive a housing subsidy. Costs of houses have jumped 150 to 300 percent in the past few years. Also the rental subsidy system of both government and other employers is a disincentive to private owner-occupancy.

Currently there are several government housing programs, chiefly administered by the Northwest Territories Housing Corporation, which is located in Yellowknife. All government programs combined provided about 1,600 houses in N.W.T. between 1969 and 1974, and 532 of these were in the Mackenzie region. In September 1973 the average capital cost of a new government rental unit was $18,000.

Particularly critical shortages of houses for the near future are apparent in Fort Simpson, Inuvik, Aklavik, Tuktoyaktuk, Fort McPherson and Wrigley. Norman Wells lacks adequate housing for Natives who come from outlying communities seeking employment.

Studies indicate that adequate housing is a prime factor in attracting northerners, white or Native, to employment opportunities and retaining them on the job. It is also known that many Natives prefer to remain in their home communities and rotate to jobs. In planning for future housing, careful attention should be directed to these factors, as one cannot now predict accurately how many northerners would be willing to move to centers and how many Natives would be likely to remain in their settlements and take only part-time employment.

The shortage of housing, the variation in quality of the units, and the small size of many units contribute to many undesirable social and economic problems. Among these are unemployment and rapid labor turnover, poor health, alcohol abuse, absenteeism, and racial tensions.

Alberta

Although there is a dearth of information available on the status of Alberta's housing industry and housing availability rate, presumably the pipeline employees would encounter a shortage of housing in the areas that the pipeline crosses in less populated parts of northern Alberta. As the pipeline moves south and comes within 40-50 miles of Calgary, housing availability should improve. In 1971 there were about 121,000 dwelling units in Calgary, 60% or 73,000 of which were single family detached units. In that same year there were about 9,000 new housing starts - a 7.4% rate.

Table 2.1.2.10-6 Housing stock in Northwest Territories

Category	Percent of Total Stock
Territorial Rental Housing	2.5
Northern Rental Housing	33.5
Public Housing	1.5
N.W.T. Employee Accommodation	19.0
Federal Employee Accommodation	9.0
Non-Government Rental Housing	25.5
Occupant Owned Non-rental	7.0
Other	2.0
	100.0%

Source: *Report of the N.W.T. Council Task Force on Housing*, T.H. Butters, Chairman (Yellowknife: Department of Information, 1972), pp. 13-14.

Education, Health, and Other Services

Education

To some extent the regional unemployment problem and low incomes reflect the lack of education and skills that would qualify the working-age population for satisfying and rewarding jobs. The 1969 DIAND survey showed that 38 percent of the Native population in the N.W.T. had never attended a school, and an additional 46 percent had not gone beyond grade 8. This is in contrast to 30 percent of the 1973 Canadian population that had 8 years or less of formal education.

The current situation is more encouraging, in terms of school enrollment. A substantial number of the young are in elementary schools and some go on to secondary or vocational schools; however, the dropout rate is high. There is a growing trend for enrollment in post-secondary and technical training courses, and few of those with such training have a problem in finding suitable work in the study region.

The Territorial and Federal Governments have organized the secondary and post-secondary educational systems along the patterns that are employed in the provinces. During the 12 school years, the northern schools are guided by policies set by the Territorial Departments of Education.

After the grades 1-12 school system, further education and training is the responsibility of other departments or special divisions within the Department of Education. In the N.W.T., these are handled by the Division of Continuing and Special Education and the Department of Local Government, and in Yukon Territory, by the Vocational and Technical Training Branch of the Department of Education. Young adults who have been out of the regular school system for one year, and are one year past the regular age for leaving school, become eligible for a number of programs administered by the Federal Department of Manpower and Immigration. These programs are administered from Manpower Centres in both Territories.

Expenditures on education by the Territorial Government in 1972-73 were estimated to be $29,401,900, including $9 million in capital expenditures. This total is 27 percent of the total Territorial budget.

Based on detailed descriptions of 23 communities in the study region in 1972-73, only two, Colville Lake and Trout Lake, had no school facilities, seven had school grades 1 through 6, four had grades 1 through 8, five had grades 1 through 9, and five had grades 1 through 12. In addition, Yellowknife had a vocational training program. At least 7 communities had hostels to house students from outlying areas. These schools are supported by government funds and by local tax levies in the few largest communities. The hostels are operated by church groups under contract to the Territorial Government.

An Adult Vocational Training Centre, located in Fort Smith, is operated by the Territorial Department of Education in cooperation with the Federal Department of Manpower and Immigration. This program is directed toward qualifying the students for employment, but also offers courses for academic upgrading to prepare for further education. Several other educational programs are also offered in the N.W.T. to provide training in such fields as trapping, prospecting, guiding, and apprenticeship in various trades. Adult Education Centres are located in Fort Good Hope and Fort McPherson. The Territorial residents may also participate in the other educational and training programs that are available in the Provinces.

The Applicant has established and implemented, in cooperation with the Federal and Territorial Governments, a Northern Training Program that is designed to train northern Natives for employment in pipeline construction and operations and in the petroleum industry in general. There were 73 training positions in this program in 1973 and 105 in 1975, not all of which have been filled.

Education in Alberta is on a 12 grade system with over 400,000 pupils enrolled annually at elementary and secondary schools. There are also about 6,000 students in institutes of technology and over 27,000 at the university level. The Province outlines the school curriculum and maintains general supervision of the elementary and secondary school systems but administration is through elected school boards.

Institutes of technology in both Edmonton and Calgary provide extensive vocational training. Universities are located in Edmonton, Calgary, and Lethbridge. There are also eight junior colleges and three agricultural colleges.

Health

Health care of some type was provided by the government in all but 4 of the 23 communities in the Northwest Territories. Only lay dispensers were available in Arctic Red River and Colville Lake; nurses and nursing stations were provided in 11 of the communities; and 6 communities had hospitals, doctors, and in some cases dentists.

The Alberta health-care insurance plan and the Alberta hospitalization benefit plan provide for all the basic health services through payment of an annual premium. Private insurance plans provide for supplementary hospitals, drug, and other services, while mental hospitals are Provided under a special Provincial act. The costs of social assistance programs are borne jointly by Federal, Provincial, and municipal activities.

Other Services

Service activities related to the communities can be broadly subdivided into communications, utilities, wholesale and retail trade, finance, community services, personal services, service for businesses, tourist service, contracting and building, and government. Transportation on a regional scale is in some degree related to all these activities.

Most service activities are not well developed in the study region because it has been difficult for northerners to open their own businesses, owing to shortages of stable and qualified labor, high transportation costs, seasonal nature of many businesses, and inadequate opportunities to bid for contracts tendered by southern firms. Many of the services now require upgrading or expansion to keep pace with the normal population growth and social needs.

Waste Disposal and Water Supply--Water-supply, and sewage and refuse-disposal facilities in the 23 Northwest Territories communities are in general substandard from either adequacy or health standpoints, or both (Grainge et al., 1973). Many of the smaller communities use hand-carried or informal water delivery, and in most of the larger and rapidly growing communities where water is treated and piped or commercially delivered, the use of facilities has nearly reached or exceeded maximum capacity. In most smaller communities, and in parts of some larger ones, sewage is collected in privies or honey buckets, and the method of disposal varies from unorganized to trucking to pits, simple treatment ponds, or tanks. A few of the largest communities have sewer systems or organized disposal systems. In most cases there is some provision for orderly refuse disposal, but a few places still use individual dumps or use a river for dumping. In the Northwest Territories, Inuvik is the only town in proximity to the line where there are waste disposal facilities capable of handling increased loads.

In the Provinces, it is generally expected that adequate waste disposal and water supply will be available in most areas.

Communications--Two-way voice or data transmission facilities are now considered inadequate in many communities. However, the telecommunication network between communities is being upgraded with a 300-channel microwave system extending to Norman Wells, and other improvements are planned.

Unique Features of Northwest Territories Study Area

As has been mentioned, each community in the study region may be regarded as unique. However, there are some features that are unique to the region in contrast to conditions in Canada south of approximately 60° N. latitude.

Among the features unique to the northern Territories are: the form of government and administration, which is now undergoing rapid change; the growing participation of the Native groups in local and Territorial political matters, a field in which they have had little previous experience; the contrasts in lifestyles between groups who primarly live off the land and those who live under urban, wage-economy conditions; the conflict and uncertainty about land rights, use and ownership; the dichotomy of housing policies and conditions between government and nongovernment workers; the ethnic and cultural differences inherent in the mix of Eskimo, Indian, Metis, and White groups; and the diversity of attitudes and desires of the people in regard to the course that future economic, social, and political planning should take. Another unique feature, which defies an adequate description, is the "northern" or frontier" attitude that is common in various degrees to nearly all people who are permanent residents of a region such as this. It is a combination of fierce independence, a pride of self-reliance, a resentment or distrust of outside authority, and a desire to determine as individuals or small groups their own lifestyle and destiny.

Area Trends

Population

The population trend for the entire N.W.T. is obviously upward; for example, 6,507 in 1911, 22,998 in 1961, and 34,805 in 1971. A characteristic of frontier areas is that males make up substantially more than 50 percent of the population until the isolated areas become more settled, by which time the male-female balance is nearly equal. This trend is becoming apparent in the N.W.T. In 1961 females made up 44.25 percent of the population, and in 1971 they were 47.46 percent; the projected figure for 1981 is 49.56 percent, if there is no influx of construction workers.

The trend for ethnic Native groups is toward a lower percentage of the total N.W.T. population. In 1961 Indians made up 22.7 percent, but only 17 percent in 1971. Eskimos show a similar decline from 34.8 to 32.7 percent during this 10-year period.

A breakdown of the total population for 17 communities in the study region in 1961, 1966, and 1971 is shown in Table 2.1.2.10-7. Total population has increased from 6,443 in 1961 to 8,282 in 1966, and 10,490 in 1971. The total estimated population for the study region in 1971 is about 23,660. A summary of changes within the study subregions by ethnic groups over the period 1931 to 1971 is shown in Table 2.1.2.10-8. Over this period more dramatic trends are apparent in the decreasing percentages of the two Native ethnic groups.

Trends by age group and sex in the N.W.T. for the period 1951 to 1971 are shown in Table 2.1.2.10-9. One outstanding feature is the large percentages of people in the age groups 39 years and younger; the total in these groups has increased from 79.2 percent in 1951 to 81.1 percent in 1961, and 83.0 percent in 1971. Approximately half of the group in each of these 3 years was in the age bracket of 14 years or less. Within the study region currently, the largest proportion of the Native population is in the 0-13 years age group, but for others it is in the 14-44 years age group.

In the absence of the proposed project, or any alternative development that would have an equivalent impact, the projected population increase has been estimated to be about 18 percent (23,600 to 27,800) between 1971 and 1975, and 36 percent (27,800 to 38,400) between 1975 and 1985. These projected figures, given by subregions, are shown in Table 2.1.2.10-10. These projected figures may be too high, in part because they are based on recent rates of increase that reflect the influence of petroleum exploration and related activities. It is reasonable to assume that without the proposed project the other petroleum activities would decline, and, although an attempt was made to be conservative and compensate for this, the effect of reduced migration into the region, especially to centers such as Inuvik, may not have been sufficiently discounted.

The implied population increase for Yellowknife is 61 percent between 1971 and 1985, yielding a 1985 population of 11,700. This is apt to be a more accurate prediction, inasmuch as Yellowknife is a primary service center and the locus of most of the Territorial and Federal Government activity.

Projections to 1985, in the absence of the proposed pipeline, have been made for the working age (15 to 64 years) population, its male component, and the ethnic makeup of the male group. It seems

Table 2.1.2.10-7 Enumeration area populations, 1961-1966-1971, by sex and ethnic origin

SETTLEMENT	1961 MALE				1961 FEMALE				M 1966 F		1971 MALE				1971 FEMALE				M & F 1971 TOTAL
	Indian	Eskimo	Other	Total	Indian	Eskimo	Other	Total			Indian[3]	Eskimo	Other[4]	Total	Indian[3]	Eskimo	Other[4]	Total	
AKLAVIK	55	91	137	283	71	106	108	285	308	303	90	140	110	340	105	150	80	340	675
ARCTIC RED R.	-	-	-	-	-	-	-	-	-	-	55	-	15	75	40	-	5	40	115
COLVILLE LAKE	-	-	-	-	-	-	-	-	-	-	30	-	5	35	30	-	-	30	65
HAY RIVER & ENTERPRISE	150	0	612	762	137	0	439	576	1074	928	295	5	985	1280	270	5	885	1160	2445
FORT FRANKLIN	110	0	4	114	123	0	1	124	145	166	145	-	20	175	155	-	15	165	340
FORT GOOD HOPE	121	5	26	152	124	5	11	140	169	166	135	-	25	150	145	-	25	170	320
FT. LIARD	73	0	12	85	61	1	7	69	98	79	115	-	5	125	85	-	5	90	215
FORT McPHERSON	150	3	73	226	215	7	61	283	319	335	265	5	70	340	290	-	55	350	695
FORT NORMAN	64	0	31	95	61	0	33	94	110	106	100	-	40	140	90	-	25	105	250
FORT PROVIDENCE	184	0	31	215	164	0	23	187	189	189	250	-	65	315	230	-	55	285	600
FORT SIMPSON	175	0	116	291	165	13	94	272	350	362	195	-	165	370	210	5	165	380	745
FORT WRIGLEY	51	0	7	58	65	0	5	70	72	64	65	-	10	75	65	-	10	75	150
INUVIK	69	113	436	618	90	137	403	630	1032	1008	135	220	1010	1365	150	260	870	1285	2645
JEAN MARIE R. & NAHANNI BUTTE	42	0	13	55	44	0	9	53	-	-	55	-	-	55	55	-	5	55	110
KAKISA LAKE & TROUT LAKE	-	-	-	-	-	-	-	-	-	-	15	-	120	130	10	-	75	85	215
NORMAN WELLS	13	2	197	212	17	0	68	85	118	81	15	5	150	175	25	-	95	125	300
TUKTOY-AKTUK	0	226	0	226	2	164	17	183	290	221	15	280	25	320	10	245	25	285	605
TOTAL	1257	440	1695	3392	1339	433	1279	3051	4274	4008	1975	655	2820	5465	1965	665	2395	5025	10490

ALL DATA OBTAINED FROM STATISTICS CANADA PUBLICATIONS (Rows may not always add to the total due to random rounding of the Census Data.)

[1] 1966 - Population by sex only--figures not available.

[2] E.A. - Enumeration Area.

[3] Includes non-band or non-treaty Indians along with Métis people as well as treaty or band Indians.

[4] Includes only those persons not categorized as Eskimos or identified in '3' above.

(-) -- Figures not available.

Table 2.1.2.10-8 Ethnic composition of total study region population, 1931-1971

	INDIAN				
Sub-Region	1931	1941	1951	1961	1971
			(Percent)		
Lower Mackenzie/Delta	68.6	47.8	41.2	24.9	19.7
Central Mackenzie	92.1	89.9	72.2	65.3	67.6
Upper Mackenzie	83.3	87.3	77.2	73.4	61.9
Slave	89.1	89.9	32.6	27.0	19.0
Northern Yukon	n.a.	n.a.	n.a.	n.a.	n.a.
Total Region	83.9	76.0	43.1	34.8	25.8

	INUIT				
Sub-Region	1931	1941	1951	1961	1971
			(Percent)		
Lower Mackenzie/Delta	16.9	37.2	41.4	27.5	31.5
Central Mackenzie	0	0	0	0.2	0
Upper Mackenzie	0.5	0	0	0	0
Slave	0.7	0	0	0.3	0
Northern Yukon	n.a.	n.a.	n.a.	n.a.	n.a.
Total Region	4.2	11.9	8.7	7.4	7.3

	OTHER				
Sub-Region	1931	1941	1951	1961	1971
			(Percent)		
Lower Mackenzie/Delta	14.5	15.0	17.4	47.6	48.8
Central Mackenzie	7.9	10.0	27.8	34.5	32.4
Upper Mackenzie	16.2	12.7	22.8	26.6	38.1
Slave	10.2	10.1	67.4	72.7	81.0
Northern Yukon	n.a.	n.a.	n.a.	n.a.	n.a.
Total Region	12.0	12.1	48.3	57.8	64.6

Notes: NA = Not Available
Figures may not sum exactly to totals indicated due to rounding.

Source: Dominion Bureau of Statistics and Statistics Canada, Censuses of Canada, 1931-1961; 1971 data from statistics developed by Gemini North Ltd. from field surveys, band lists and information obtained from the N.W.T. Government.

Table 2.1.2.10-9 Population by age group and sex, Northwest Territories: 1951-1971

	Total: Males and Females					
Age Group	1951		1961		1971	
	No.	%	No.	%	No.	%
0-4	2,527	15.8	3,890	16.9	5,475	15.7
5-9	1,838	11.5	2,924	12.7	5,390	15.5
10-14	1,461	9.1	2,413	10.5	4,075	11.7
15-19	1,428	8.9	1,699	7.4	2,990	8.6
20-24	1,620	10.1	2,239	9.7	3,435	9.9
25-29	1,485	9.3	2,156	9.4	3,110	8.9
30-34	1,286	8.0	1,849	8.0	2,405	6.9
35-39	1,039	6.5	1,483	6.5	2,005	5.8
40-44	873	5.5	1,146	5.0	1,545	4.4
45-49	706	4.4	930	4.0	1,305	3.8
50-54	565	3.5	752	3.3	990	2.8
55-59	416	2.6	551	2.4	740	2.1
60-64	330	2.1	372	1.6	585	1.7
65-69	172	1.1	260	1.1	325	0.9
70 +	258	1.6	334	1.5	430	1.2
TOTAL	16,004	100.0	22,998	100.0	34,805	99.9

	Males					
Age Group	1951		1961		1971	
	No.	%	No.	%	No.	%
0-4	1,280	14.1	1,976	15.4	2,815	15.4
5-9	947	10.5	1,532	11.9	2,770	15.2
10-14	749	8.3	1,215	9.5	2,110	11.5
15-19	767	8.5	905	7.1	1,500	8.2
20-24	1,014	11.2	1,310	10.2	1,755	9.6
25-29	904	10.0	1,280	10.0	1,655	9.1
30-34	769	8.5	1,123	8.7	1,280	7.0
35-39	593	6.5	875	6.8	1,100	6.0
40-44	541	6.0	674	5.2	845	4.6
45-49	448	4.9	546	4.3	730	4.0
50-54	331	3.6	482	3.8	550	3.0
55-59	245	2.7	343	2.7	415	2.3
60-64	225	2.5	213	1.7	350	1.9
65-69	96	1.1	151	1.2	180	1.0
70 +	144	1.6	197	1.5	225	1.2
TOTAL	9,053	100.0	12,822	100.0	18,280	100.0

	Females					
Age Group	1951		1961		1971	
	No.	%	No.	%	No.	%
0-4	1,247	17.9	1,914	18.8	2,660	16.1
5-9	891	12.8	1,392	13.7	2,615	15.8
10-14	712	10.3	1,198	11.8	1,970	11.9
15-19	661	9.5	794	7.8	1,495	9.0
20-24	606	8.7	929	9.1	1,680	10.2
25-29	581	8.4	876	8.6	1,455	8.8
30-34	517	7.4	726	7.1	1,125	6.8
35-39	446	6.4	608	6.0	905	5.5
40-44	332	4.8	472	4.6	700	4.2
45-49	258	3.7	384	3.8	575	3.5
50-54	234	3.4	270	2.6	440	2.7
55-59	171	2.5	208	2.0	320	1.9
60-64	105	1.5	159	1.6	230	1.4
65-69	76	1.1	109	1.1	145	0.9
70 +	114	1.6	137	1.4	210	1.3
TOTAL	6,951	100.0	10,176	100.0	16,525	100.0

Note: Figures may not sum exactly to totals indicated due to rounding.

Source: Statistics Canada. 1971 Census of Canada - Population by Age Group, 1973.

Table 2.1.2.10-10 Projected population by sub-region, 1975-1985--without the pipeline

Sub-Region	1971	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Lower Mackenzie/Delta	5,472	6,430	6,672	6,913	7,160	7,405	7,644	7,899	8,145	8,389	8,632	8,874
Central Mackenzie	1,499	1,761	1,828	1,894	1,961	2,029	2,095	2,164	2,231	2,298	2,365	2,431
Upper Mackenzie	1,602	1,883	1,953	2,024	2,096	2,168	2,329	2,312	2,385	2,456	2,527	2,598
Slave	14,873	17,477	18,135	18,789	19,460	20,129	20,792	21,468	22,139	22,802	23,463	24,120
Northern Yukon	216	254	263	273	283	292	302	312	322	331	341	351
TOTAL	23,662	27,805	28,851	29,893	30,960	32,023	33,077	34,155	35,222	36,276	37,328	38,374

Source: Gemini North Ltd. to 1983; extended by Applicant to 1985.

reasonable to expect that the subregional and community distributions would remain approximately the same as in 1971. It is estimated (Table 2.1.2.10-11) that the total labor force should increase steadily from 13,549 in 1971 to 24,721 in 1985. About 55 percent of this 1971 total is male, and in 1985 about 53 percent is assumed to be male. The Indian and Inuit portion of the male working age group (Table 2.1.2.10-12) would rise from 2,051 in 1971 to 3,224 in 1985, a decrease from about 27 to 24 percent of the male totals.

Another method of projecting the growth of working age population over the period 1971 to 1981 results in a slightly lower total of approximately 18,500 (9,600 males and 8,900 females) for the study region in 1981. The details of this projection, broken down by subregion and sex are given in Table 2.1.2.10-13.

Community Structure

Local Government

The trend in recent years is toward community organization, individual and group concern with and participation in community affairs and problems, and delegation by the Federal and Territorial Governments of a much greater degree of responsibility for self-determination. Much of this trend has been reinforced by and is in response to the socio-economic transition from a nomadic subsistence, land-related lifestyle to an employment and wage economy centered more around a relatively stable community.

Historically, the individual settlements were dominated politically by the RCMP, the priest, the "Bay Man" (Hudson's Bay Company) or trading post operator, and the government agent. This created a dependence, apathy and sense of noninvolvement among the residents. The only indigenous political unit was the band council, which depended for effectiveness on the strength and popularity of the chief and his counselors. With the implementation in 1967 of recommendations of the Carrothers Commission, local government with elected councils within the settlement, hamlet, village, town, and city framework was established. This has had mixed benefits and detriments, and the net result is to a large extent determined by the makeup of the individual community. It has expanded job opportunities and increased involvement of the residents in the decision-making process. In some cases it has created tensions and backlash among residents who were unfamiliar with or unable to cope with such community responsibilities. However, as the residents learn to deal with their problems, some of the complaints appear to diminish. The powers of the band chief and council have been eroded by the substitution of an elected council based on community, rather than ethnic, affiliation. Again, the impact of this change depends upon conditions in the particular community, particularly its ethnic makeup.

There is a trend, in some communities and ethnic groups, of growing resentment toward "outsiders" and/or whites, and a resistance to utilization of the land and resources surrounding the community without that community's consent. This is manifested through the local council, as well as by the territorial ethnic-interest groups. Unfortunately, individual Natives, and to some extent the local and ethnic groups, have opposing views of development activities versus keeping "outsiders" off the land. On the basis of numerous interviews with individual residents, it appears that there is no consensus.

Table 2.1.2.10-11 Projected total and male working age population in the study region, 1971-1985--without the pipeline

(Population 15-64 Years Old)

Year	Total	Male
1971	13,549	7,554
1972	14,150	7,830
1973	14,775	8,110
1974	15,435	8,415
1975	16,150	8,740
1976	16,875	9,089
1977	17,605	9,445
1978	18,380	9,820
1979	19,185	10,235
1980	20,050	10,675
1981	20,938	11,131
1982	21,835	11,595
1983	22,770	12,090
1984	23,729	12,610
1985	24,721	13,159

Source: Gemini North Ltd. to 1983; extended to 1985 by the Applicant.

Table 2.1.2.10-12 Ethnic composition of projected male working age population in the study region, selected years--without the pipeline

Ethnic Group	Working Age Population				
	1971	1976	1981	1983	1985
Indian	1,610	1,847	2,164	2,330	2,503
Inuit	441	509	610	660	721
Other	5,503	6,733	8,357	9,100	9,935
TOTAL STUDY REGION	7,554	9,089	11,131	12,090	13,159

Source: Gemini North Ltd. to 1983; extended to 1985 by the Applicant.

Table 2.1.2.10-13 Low projection of working age population, 1971, 1976, 1981

	1971 (Base Year)	1976[1]	1981[1]
Lower Mackenzie/Delta			
Males	1,455	1,799	2,210
Females	1,429	1,729	2,093
TOTAL	2,884	3,528	4,303
Central Mackenzie			
Males	390	426	510
Females	357	431	518
TOTAL	747	857	1,028
Upper Mackenzie			
Males	442	505	611
Females	386	500	613
TOTAL	828	1,005	1,224
Slave			
Males	4,659	5,402	6,248
Females	4,108	4,783	5,611
TOTAL	8,767	10,185	11,859
Northern Yukon - Old Crow			
Males	49	59	72
Females	54	66	71
TOTAL	103	125	143
TOTALS: Males	6,995	8,191	9,651
Females	6,334	7,509	8,906
GRAND TOTAL	13,329	15,700	18,557

[1] Cohort Adjustment Method - Age-sex distributions of base year populations in five year cohorts are successively "Flipped" up by five and ten years, respectively, to show projected working age population in 1976 and 1981. Thus, the 10-14 year olds enter the labour force and the 60-64 year olds exit from the labour force in 1976.

Source: Compiled by Gemini North Ltd.

Housing

Housing is one of the critical needs that is closely linked to economic growth. It is estimated that more than 300 housing units per year will be required merely to keep pace with the population increase. This is in addition to the current shortages in both quality and quantity of housing. It is likely that before 1985 additional money and effort will have to be devoted to new housing.

Health

Health is a major problem in th N.W.T. and one thing is certain--old age is not a major cause of death. In 1969 the average age at death for males was 34.4 years, and 28.9 years for females. These are in marked contrast to the overall Canadian rates of 62.9 years for males and 67.3 years for females.

Improved and expanded health care, better housing, and increased health education have dramatically improved health conditions in the N.W.T., and the study region in particular, in recent years. Basically, health problems and premature deaths stem from three causes: alcohol abuse, poor housing, sanitation and services, and venereal disease. Geographical isolation from the few widely scattered medical facilities inhibits good physical health care. Psychological isolation (a state of mind related to "being out of touch," to the severe climatic conditions, and to the lack of recreational outlets) accentuates mental health problems. This condition is also called "cabin fever."

Major Social Problems

There are several major problems in the northern Territories, and the study region in particular, that must be recognized. These are alcohol abuse, crime, and welfare and subsidy payments. By far the most critical of these is alcohol abuse, and it is largely responsible for many of the difficulties in the other two problem areas.

Alcohol Abuse--Alcohol abuse is recognized as the major social problem in the north. It cuts across most facets of northern life. Law enforcement people estimate that their work would be cut by 75 percent in the absence of alcohol abuse, and welfare authorities attribute 98 percent of child neglect cases to excessive use of alcohol. Alcohol abuse is ingrained in the northern lifestyle, it is worse in rapidly developing communities, and it is expected to become a greater problem in association with future developments. It appears that existing mechanisms for offsetting the anticipated increase in abuse are totally inadequate.

Alcoholic beverage consumption figures must be examined carefully to appreciate one of the roots of the alcohol problem. The average per capita consumption of alcoholic beverages in the N.W.T. is 19 percent lower than the Canadian average. However, in the N.W.T. the consumption of hard liquor is 36 percent higher, of beer is 24 percent lower, and of wine is about the same.

Crime--The crime rate in the N.W.T. is increasing. Some rates of crime are 10 times the overall Canadian rate. The single most important factor in the increase in violent crime is the abuse of alcohol. Other factors are related to an increase in development pressures, and include increases in cash income, population, and exposure to the outside world. The overall crime rate has increased from 16 crimes per 100 population in 1968 to 30 per 100 population in 1972. Liquor ordinance violations are listed as violations of Territorial ordinances and not as crimes, and it appears that such violations account for about 90 percent of all ordinance violations other than traffic citations.

Welfare and Subsidy Payments--The fields of welfare and subsidy payments are complex and influenced by many factors, and the somewhat limited data relating to them can be interpreted in various subjective ways. Welfare payments, which have been increasing in recent years, are in some measure related to the transition from a land-based to a wage-based economy and attendant disruption of the socio-economic environment. Some people suggest that as the Natives are exposed to new and better standards of living their desires and needs for cash increase. Subsidy payments have led to a 2-tier socioeconomic society, often coincident with ethnic groups, and also divided by a government and nongovernment employee line. Subsidized and nonsubsidized housing units exist in close proximity, and the obvious disparities breed social tensions that divide ethnic groups, employment groups, and resident and transient groups.

2.1.2.11 Land Use

Most of the approximately 43,060 acres that would be used during the construction and operation of a gas pipeline following the proposed route is not under extensive development.

North of latitude 60° N latitude (in the Northwest and Yukon Territories) the proposed route, except for the supply lines, generally follows the Mackenzie River through a quasiwilderness that until recently has provided the subsistence base for a hunting and gathering economy of Native peoples. Land use was the same in the Arctic tundra that would be crossed by the proposed supply lines from Richards Island and Prudhoe Bay. Since the general area was first explored by Alexander Mackenzie (1789) and those who followed him, there have been trading posts such as Fort Good Hope, Arctic Red River, and Fort McPherson. For many years before whaling ceased in the Beaufort Sea in 1912, Native peoples also had contacts (including employment) with whites. Most trading was in the exchange of furs for nonindigenous goods such as sugar, tea, and tobacco. These activities involved no change in land-use patterns from those before the advent of the white man.

The first modern industrial event in the Mackenzie Valley was the drilling of an oil well at Norman Wells in 1920 and the construction of a refinery there in the 1930's. In the 1930's gold and uranium mines were opened east of the Mackenzie River and an influx of white prospectors and settlers began, followed during and after World War II by the construction of military posts and highways. Oil and gas exploration, mining, and, to a much lesser extent, agriculture and logging are economic developments of the last few years that have caused changes in land use in the Northwest Territories. Most of the areas affected, however, are not near the proposed route.

The north end of the Dempster Highway from Dawson, Y.T., to Inuvik is near the proposed Prudhoe Bay and Richards Island Supply Lines near the western edge of the Mackenzie Delta and from

Travaillant Lake Junction to Inuvik, respectively (Figure 2.1.2.10-3). The Dempster Highway has not been completed and no target date for its completion has been announced. As of October, 1975, it was stated (Department of Indian and Northern Affairs) that the highway "could be completed by 1978 if sufficient funds are made available."

The proposed Mackenzie Highway route generally follows the east bank of the Mackenzie River from a crossing near Camsell Bend (about 62° 15' N latitude), northwest of Fort Simpson, to its junction with the Dempster Highway near Inuvik. The highway has been constructed as far north as Willowlake River and is a proposed route from there to Inuvik. As of October, 1975, the construction program called for completion of the highway to Wrigley by 1978, with no plans for completion beyond that point (Dept. of Indian and Northern Affairs).

For most of the distance the proposed highway and pipeline routes are within 2 miles of each other.

From the River Between Two Mountains (Milepost 583), about 30 miles southeast of Wrigley, the proposed pipeline route diverges from the highway route and for 30 miles they are separated by as much as 13-20 miles, and then converge and are about 6 miles apart at the pipeline crossing of the Mackenzie River, upstream from Fort Simpson. South of Fort Simpson, for a pipeline distance of about 32 miles, the two routes are again separated by as much as 19 miles. At pipeline Milepost 722 the highway crosses the proposed pipeline route and diverges sharply to the east. From this point to oil and gas fields about 20 miles north of the Hay River (at about 59° 15' N. latitude) the proposed route is not near established transportation routes.

From the Hay River to the Canada-U.S. boundary (about 1,195 miles) the proposed route, including the Monchy and Kingsgate Delivery Lines, is close to established transportation facilities. For 71 percent (about 850 miles) of the proposed routes existing parallel pipelines are within a few hundred feet (maps in Section 2.1.2.2). For the 171 miles of the proposed Monchy Delivery Line not immediately parallel to an existing pipeline, much of the area traversed is crossed by roads on one- or two-mile spacings.

Vegetation along the proposed route and its supply and distribution lines varies from grassland tundra at the Beaufort Sea coast through several types of forest to grassland, now largely under agriculture, in Saskatchewan. Low tundra vegetation grows along about half of the proposed supply line routes and merges with forest-tundra, which extends south to the vicinity of Norman Wells. The forest-tundra zone is characterized by a wide variety of vegetation types. Wet lands support scattered black spruce, tamarack, and various kinds of low vegetation. Riparian communities consist of white spruce and an understory of tall shrubs and are best developed in the Mackenzie Delta. Mature forest-tundra communities, usually with black spruce the dominant tree, cover more than half of the northern Mackenzie Valley. Grasses, shrubs, and various hardwoods form successional communities after forest fires, which have burned 17 percent of the forested area in the northern Mackenzie Valley within the last 10 years.

Boreal forest gradually supplants forest-tundra types near Norman Wells. Dominant tree species are white and black spruce, balsam poplar, aspen, jack and lodgepole pines, and white birch, with deciduous trees becoming relatively more numerous in northwestern Alberta. Excellent merchantable white spruce occurs on the floodplains of the Liard and lower Peace Rivers near the proposed route.

From the Peace River region southward to Caroline Junction the proposed route is generally through forests similar to those to the north except for the addition of minor numbers of two species of fir. Interspersed with forest are several oil fields and westward extensions of the major agricultural area of Alberta, which is a few miles east of the proposed route. From Caroline Junction to the British Columbia-Idaho boundary the proposed route of the Kingsgate Delivery Line crosses agricultural land east of the Rocky Mountain front and then is through Douglas fir-Engelmann spruce-pine forest. In British Columbia most of the land is in provincial forests; some has been extensively logged. The proposed Monchy Delivery Line would cross a region where land utilization for farming approaches 100 percent in some areas and is everywhere important. Croplands and pasture, both improved and unimproved, occupy most of the region between Caroline Junction and Monchy, Sask., except for a military reserve in eastern Alberta.

Agricultural products are mainly grain, edible-oil seed, and cattle; many ranches raise both, with cattle either out to pasture or fattened on grain. The primary agricultural area extends from the Peace River region of Alberta to the Canada-U.S. boundary east of the Rocky Mountain front.

Developed mineral industries along the proposed route consist mainly of a chain of oil and gas fields from the Hay River in northwestern Alberta along the Rocky Mountain Front nearly to the Alberta-British Columbia boundary. About two-thirds of the oil and gas potential of this petroleum resource is considered to have been discovered. Farther north a small oil field that contains no gas is at Norman Wells. The second most important developed mineral resource is coal, mainly from the Crowsnest coalfield, which straddles the Provincial boundary between Alberta and British Columbia and is crossed by the proposed route of the Kingsgate Delivery Line at Crowsnest Pass. Other developed coalfields are in the Bow River valley west of the proposed Kingsgate Delivery Line near Calgary. Undeveloped coal beds are known near the proposed route near Norman Wells. Most of the route of the proposed Monchy Delivery Line crosses areas underlain by subbituminous coal and lignite, all undeveloped. Industrial and nonmetallic mineral resources are known near the proposed route in Alberta and southwestern Saskatchewan, but not close enough to be directly affected by possible pipeline construction and operation. Known metallic-mineral and gypsum deposits in southeastern British Columbia are all north of the proposed Kingsgate Delivery Line.

The proposed route, including supply and distribution lines, does not cross any urban areas, though it passes within a few miles of settlements in the Northwest Territories and through the outskirts of several small towns in Alberta, Saskatchewan, and British Columbia.

Tourism is not a major industry in the immediate vicinity of the proposed route, but is important in the mountains west of the route in Alberta and, to a lesser extent, in southeastern British Columbia.

2.1.2.12 Paleontological, Archeological, Historical

The proposed pipeline would traverse the area through which early man is believed to have traveled after crossing the Bering land bridge into North America. It will follow the Mackenzie corridor through which he probably migrated south and cross many of the characteristic habitats occupied and used by neolithic man in the last 30,000 years. The following section is based on data submitted by Canadian Arctic Gas Pipeline Limited and the Environment Protection Board to Canadian governmental agencies, and deals mainly with the proposed pipeline route north of 60° N latitude. The proposed Main Line south of 60° N latitude would parallel existing pipelines for about 395 miles (about 2/3 of its length). The proposed Monchy Delivery Line will follow the route of existing pipelines for about 1/2 its length and most of this line (about 90%) will cross through agricultural lands. The proposed Kingsgate Delivery Line will parallel existing pipelines for all but about 25 miles of its 282-mile length. Therefore, most of the proposed route south of 60° N latitude will cross areas of low potential for the discovery of undisturbed archeological sites.

Known Sites

North of the 60° N latitude, a number of archeological and historic sites along the proposed route have been investigated (Millar, 1974), including the following:

1) Prudhoe Bay Supply Line
    - Firth River Valley
    - Babbage River
    - Old Fort McPherson
2) Richards Island Supply Line and Main Line to 60° N. latitude
    - East branch Mackenzie River, near mouth

    Great Bear River

    - Several sites between Fort Simpson and Fort Good Hope
    - Oscar Creek and Chick Lake
    - Lower Willowlake River near confluence with Mackenzie River
    - River Between Two Mountains
    - Ochre and Johnson Rivers
    - Old Fort Alexander
    - Old Fort Wrigley
    - Three previous sites of Fort Norman

In Saskatchewan, the proposed Monchy Delivery Line will pass near two of the 143 marked sites of historic interest in the Province--Fort Walsh and Chesterfield House.

Presently there are no unique or unusual paleontological sites known along the route of the proposed project, although any area of exposed bedrock could possibly yield fossils. Such bedrock areas will be infrequently encountered by the proposed pipeline. The Kingsgate Delivery Line is the only segment where significant areas of bedrock would be traversed.

Proposed or Planned Sites or Areas

A proposal for archeological salvage along the proposed route from the Yukon-Alaska border and Richards Island to 60° N latitude (Millar, 1974) lists a total of 88 sites to be examined. These sites are classified in terms of priority. A high priority classification infers high probability, both in terms of prehistoric utilization strategy and of finding a site under the prevailing conditions. A medium priority classification means that there is good probability that man once used the location and there is some possibility that either surface survey or survey of the right-of-way during clearing or preparation might locate that occupation. Low priority sections have quite variable probability, from extremely low to high, but the possibility cf finding sites during route survey or preparation is minimal.

Along the Prudhoe Bay Supply Line, nine high priority sites, 13 medium priority sites, and two low priority sites have been identified (Millar, 1974). The Richards Island Supply Line and the Main Line to 60° N latitude have six high priority sites, 39 medium priority sites, and 10 low priority sites (Millar, 1974).

Potentially Significant Areas or Sites

To identify potentially significant archeological sites, an estimate of how early man used his environment and distributed himself throughout that environment is necessary. Study indicates that probable campsite locations in the western Canadian Arctic include sand spits, storm beaches, river mouths and protected bays with terraces, along the coast. Inland, likely sites include well-drained lake and river terraces, all depositional glacial features, especially those along streams or lakes, fossil beaches of late Pleistocene glacial lakes, and confluences of streams and lakeshores near inlet and outlet streams.

In non-glaciated areas there is likelihood that evidence of pre-main Wisconsin migrants or late Wisconsin occupants could be found, but glaciated areas would yield evidence only of post-glaciation inhabitants.

Archeological Background

Asia and North America are believed to have been connected by the Bering land bridge during several periods of time during the past few million years, thus providing a migration route for terrestrial mammals and eventually man. Sometime before 25,000 years ago, man may have moved via this bridge from the Old World to the New World. Small groups of nomadic hunters possessing very simple tools would have moved south to the plains via an ice-free corridor. At various times the two great ice sheets of the main Wisconsin glaciation were partially or completely separated along a line which generally conforms to the present-day Mackenzie River. Thus passage south to the interior plains was possible. Little is known of these early people other than the location of a few sites and some inferred occupations.

After the main Wisconsin stadial about 20,000 years ago, the Mackenzie Basin migration corridor opened up again as the ice melted and the glacial fronts retreated east and west. At this time, new influences must have developed along the Mackenzie Basin route into the heart of North America. The hunting of mammoth and other cold-adapted megafauna spread widely in the New World. Considerably more is known of the people of this time, whose sites have been discovered in Alaska, in the southwestern plains and adjacent mountain valleys of Canada, in the Mississippi drainage area, in the eastern U.S. and in Nova Scotia.

As the post-Pleistocene climate change proceeded, grasslands extended north to the Arctic. Men who were probably descendants of the earlier megafauna hunters then occupied most of the central and southern part of the continent. The fauna and subsequently man extended north, reaching the Arctic drainage and possibly the Arctic littoral areas. During this period, in intermontane Alaska and Yukon Territory, there appeared several varieties of a unique tool technology that ultimately may have derived from Japan and northern Asia. This technique, using small delicate tools made from slivers of stone, eventually spread through the intermontane region and east into the Mackenzie Basin.

The forest migration into the North probably occurred before 8,000 years ago and required a new adaptation and additional tools. Forest hunting, fishing and wood-working likely developed about this time. To the north, the caribou were basic to the life of the interior Indians and a seasonal resource for the coastal Eskimos. About 4,000 years ago, the earliest ancestral Eskimos moved rapidly eastward along the coast from the Bering Strait region as far as Labrador and Greenland. They combined seasonal caribou hunting with some exploitation of the marine resources in their adaptation to life in the North American Arctic.

The first evidence of man in Alberta dates from about 12,000 years ago, when the vast glacial lakes occupying the Peace River Lowland receded. Fluted points represent these earliest inhabitants, hunters of now-extinct animals such as mammoths, horses and giant bison. Similar hunters also inhabited Saskatchewan, moving in as the glacial ice that covered the area retreated northeastward about 20,000 years ago. As the climate changed, so did the flora and fauna and the life styles of the early inhabitants. Better tools and weapons were developed and the now-extinct giant bison became the mainstay of life, supplying not only meat but raw materials for tools, clothing and shelter. Little is known of these early hunters in Saskatchewan, but signs of their presence are found throughout the area.

By about 10,000 to 8,000 years ago, environmental conditions similar to those of the present became established in Alberta. By this time, cultural differentiation had taken place. On the slopes of the Rocky Mountains a distinct mountain-adapted hunting culture developed through contact with peoples of the Columbia and Fraser

Rivers areas. On the Alberta plains, with the development of a full grassland environment, bison became the economic mainstay and continued in importance until historic times. About 7,000 years ago, both man and animal appear to have migrated from the Saskatchewan plains which had become desiccated by heat and lack of precipitation, a condition which lasted for 2,000 years or more. Following this apparent hiatus, new waves of migrants entered the plains from the woodlands of the East and the mountain valleys of the West. Representative groups from both directions appear to have met in southwest Saskatchewan, where characteristics of both appear together in a number of sites. Again, bison seems to have been the main food supply, but there is more evidence of diversification, using other species of plants and animals. Tools and weapons show evidence of considerable development, projectile points decreasing in size and proliferating in style. In Alberta, some of the eastern newcomers penetrated the eastern slope of the Rockies so that by 3,000 B.C. they had become culturally distinct from the adjacent plains inhabitants and were replaced 1,500 years later by men with Late Middle Prehistoric cultures. Subsequently, this area was characterized by local adaptations reflected in different tool kits. Approximately 2,000 years ago, the manufacture and use of pottery appears to have spread into the northern plains of Alberta and Saskatchewan. At somewhat the same time, the bow and arrow may have made its appearance, facilitating hunting. At about this time, the hunters apparently began to make greater use of communal methods of hunting, using planned bison drives and jumps. Such methods continued into historic times, even after the coming of the horse.

Evidence of this period of change is sparse, but sufficient to suggest that southwestern Saskatchewan may have been a main center of development, being a meeting place for many peoples and for a merging of ideas.

In the Rocky Mountains of southeastern British Columbia, the peoples of the mountain-adapted hunting culture were forced to concentrate in the valley bottoms by a minor resurgence of mountain glaciers from about 1,000 B.C. to A.D. 400. At this time both the tool kits and economic pattern of the inhabitants of this area were similar to the Interior Plateau area.

After A.D. 400, marked changes appeared in the life style of the mountain peoples. Bison, elk and sheep were hunted in addition to the previously hunted deer. Use of local quarries for stone materials was passed over in favor of materials from high mountain quarries. These changes indicate a return to a seasonal pattern in which upland hunting was important and fishing and plant collecting declined. These people, at the beginning of the historic period, occupied the whole of the Rocky Mountains from Waterton to the Kootenay Plains and the North Saskatchewan River.

2.1.2.13 Recreational and Esthetic Resources

Recreational Facilities, Areas, and Resources

Outdoor recreation is becoming increasingly important as we enter the age of mass leisure. It offers physical and mental stimulation and helps decrease the frustrations and problems of everyday urban life. Increases in population, disposable income, leisure time, mobility, urban pressures, and other factors have contributed to the prodigious increase in outdoor recreation participation (total time and total numbers). If the present trend of increasing demand for outdoor recreation continues, more outdoor facilities and lands will be required far into the future, even though present and continuing energy shortages may well dampen some of the predicted demand.

For people in Canada and the continental United States, the Canadian North is one of the last recreation frontiers. Much of the land, including the Yukon Coastal Plain, Mackenzie Delta, Richardson Mountains, Franklin Mountains, Travaillant Lake area, and the region east of Fort Good Hope, is true wilderness; it is totally undeveloped, not easily accessible, and unpopulated. Thus, it offers new opportunities for certain outdoor recreation activities which now cannot easily be obtained elsewhere in North America. Some of the major recreation activities which can be or have been enjoyed in the northern environment include sightseeing and photography, wilderness use, hiking and backpacking, camping, hunting, fishing, collecting and nature study, white-water boating, float tripping, and snowmobiling.

The Canadian North has several advantages as a location for wildland outdoor recreation. It offers a variety of unusual landscapes, it offers a link to the past in the form of Native communities and large expanses of undisturbed land, and it offers areas where competition for hunting, fishing, and other forms of recreation is at a minimum. There are also several disadvantages. Those features of the North which offer the most unique experiences are also most susceptible to overuse. Environmental degradation could result if careful controls on outdoor recreation are not maintained. Native communities such as Arctic Red River, Inuvik, Fort Good Hope, and Wrigley could be disrupted by the influx of large numbers of recreationists. Because of the great distances between the Canadian North and major population centers, travel time and cost could be prohibitive to large numbers of North Americans. Climatic features, such as the short summer season, severe winter temperatures, and short winter daylight periods, tend to limit most recreational use to only a few summer months. As a result of the shortness of the recreation season, businesses are forced to have high rates for accommodations and other services. Good tourist-accommodation facilities and services are unavailable except at Yellowknife and Hay River. In many areas, severe insect harassment is a problem.

In British Columbia, the proposed route will cross the Elk, Flathead, and Yahk Provincial Forests. According to recent information from Alberta Natural Gas Company (written communication, 1975) the proposed pipeline would cross the Crowsnest and Ryan Provincial Parks and the Plumb Bob Creek Park Reserve. In Alberta, the proposed route will pass through the Chain Lakes Provincial Park and close to two other Provincial parks. It will pass through, or close to, five Alberta Forest Service recreation areas, which are developed and maintained for public use on lands administered by the Department of Lands and Forests and which offer only rustic facilities. Data on acreage, uses, facilities, use statistics and areas served by the various parks and recreation areas are not available. There are no official recreation facilities or areas near the proposed route in the Yukon and Northwest Territories or the Province of Saskatchewan.

Hunting and fishing are major recreational activities in nearly all parts of Alberta. Most game species of the ungulates and carnivores are found near the proposed pipeline route and are hunted extensively. Various species of upland game birds and waterfowl also range throughout the province and provide outdoor recreation in season. Cold-water sportfish such as trout, mountain whitefish and Arctic grayling can be found in 40 percent of Alberta's 12,000-13,000 miles of streams; warm-water fish such as northern pike, walleye and goldeye inhabit the remaining 60 percent. The lakes of Alberta provide both recreational angling and some commercial fishing.

The proposed route through the southeastern corner of British Columbia would pass through the Elk, Flathead and Yahk Provincial Forests. The area supports big-game species including moose, elk, bighorn sheep, mule deer, whitetail deer, mountain goat, black bear, grizzly bear, and cougar, most of which are hunted extensively. Hunting for upland game birds, particularly grouse and doves, is popular, while a paucity of suitable habitat makes waterfowl hunting relatively unimportant. The streams in this area provide fishable populations of Dolly Varden, mountain whitefish and cutthroat trout.

In southwestern Saskatchewan, big-game species such as antelope, mule and whitetail deer, as well as upland birds and waterfowl, are hunted. The Great Sand Hills area provides excellent sharp-tailed-grouse and mule-deer hunting. Many streams, lakes, and reservoirs in southwestern Saskatchewan have been stocked with rainbow, brown or brook trout; yellow, walleye and northern pike occur in some waters.

No new park areas are known to be currently proposed along the proposed route, although both Territorial and Federal Governments are examining sites north of 60° N latitude for possible designation as Federal or Territorial parks. A region that has received serious consideration for preservation as a national park is Toker Point, north of Tuktoyaktuk and some 50 miles northeast of the proposed route. This area contains a unique concentration of pingo topography. The Rat River, a former canoe route used to reach the Yukon gold-mining area, is a whitewater-canoeing-type stream and as such, has much recreational potential. Other streams offering good opportunities for wilderness canoeing include the Thunder River, Great Bear River, several streams in the vicinity of Wrigley, the Liard River and much of the Mackenzie River.

Esthetic, Scenic, and Cultural Features

For the purpose of describing the proposed pipeline route in terms of esthetics, fourteen basic areas of significantly different visual and esthetic experience have been selected (Figures 2.1.2.13-1 and -2). Each area is basically defined by its broadest visual containment and therefore, may contain several physiographic regions.

Zone A is near the Alaska-Yukon border and contains the British Mountains, Arctic Plateau, Yukon Coastal Plain and Beaufort Sea. Major features are the mountain peaks to the south with alluvial fans along the break in slope, and the Beaufort Sea to the north. The low-profile vegetation consists of dwarf shrubs, herbaceous plants, and lichen-moss ground cover. Rough, exposed land forms dominate the scenery.

Zone B is west of the Yukon-Northwest Territories boundary and is composed of the Yukon Coastal Plain and the Beaufort Sea. Major features are the Arctic shoreline, and Beaufort Sea, and the rolling hills of the Porcupine Plateau. The low-profile vegetation is similar to that of Zone A. The scenery consists of smooth, rolling topography down to the sea.

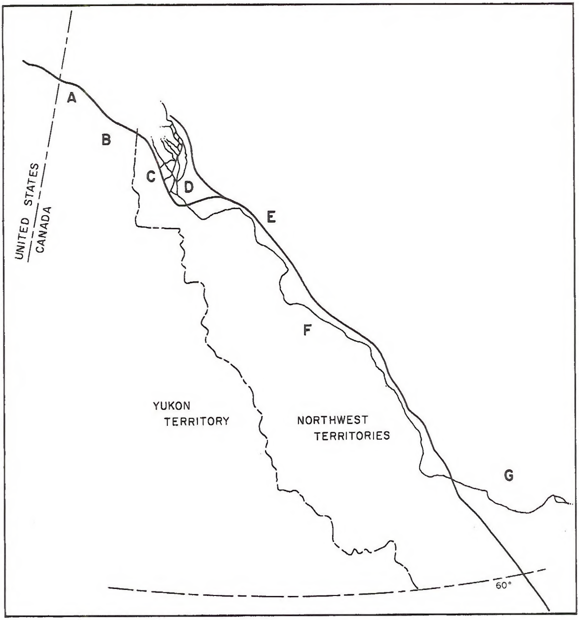


Figure 2.1.2.13-1 Zones of significantly different visual and esthetic character, Alaska-Yukon border to 60° N latitude

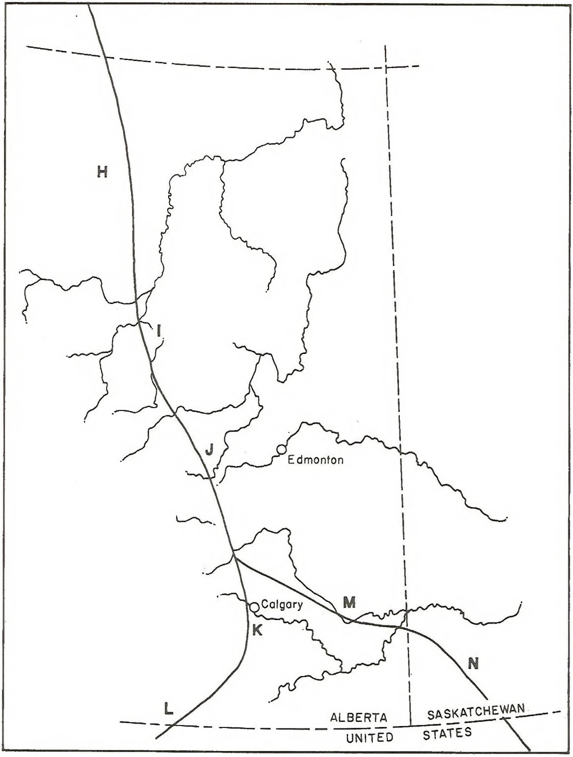


Figure 2.1.2.13-2 Zones of significantly different visual and esthetic character, 60° N latitude to 49° N latitude

Zone C is the area between the Yukon-Northwest Territories boundary and Fort McPherson, and is composed of the Richardson Mountains and the Mackenzie Delta. Major features are the mountains and foothills to the west and the braided network of river channels to the east. The vegetation consists of extensive stands of conifers along the drainage pattern of the Richardson Mountains, changing to isolated conifer stands and then to low-profile vegetation in the lowlands.

Zone D is along the route of the proposed Richards Island Supply Line in the Mackenzie Delta. Major features are lakes and the braided network of river channels in a landscape of low relief. The vegetation is mostly low profile, with dwarf shrubs, lichen-moss ground cover and scattered stands of conifers.

Zone E is the area between Travaillant Lake and Fort Good Hope. It is composed of the Anderson Plain and the Peel Plain and the major feature in its low-relief landscape is the Mackenzie River. The low-profile, scrubby vegetative cover is sporadically dotted with thin stands of conifers.

Zone F, near Norman Wells, is composed of the Mackenzie Mountains, Mackenzie Plain, and Franklin Mountains. Major features of the landscape are the Mackenzie River and its broad valley, bounded by mountains on both sides. The valley is blanketed with a continuous cover of conifers.

Zone G, near Fort Simpson, consists of the Great Slave Plain. The major landscape feature is a rolling plain blanketed with predominantly tall, dark-toned coniferous and decidous forest.

Zone H is the area between the Northwest Territories-Alberta border and the Peace River crossing of the proposed pipeline. It consists of part of the Alberta Plateau, and its consistently rolling terrain is covered by coniferous or mixed deciduous and coniferous forests.

Zone I, west of Lesser Slave Lake, is also a part of the Alberta Plateau and contains large expanses of agricultural land. The landscape is characterized by grasslands and aspen parklands widely broken by low-profile, rectilinear agricultural fields.

Zone J is the area west of Edmonton and south of the Athabasca River crossing of the proposed pipeline. The Alberta Plain and Alberta Plateau produce a landscape of level to rolling terrain, with a continuous, mostly coniferous tree cover and circular patterns of fens and marshes.

Zone K, near Calgary, Alberta, is composed of the Alberta Plain, Rocky Mountain Foothills, and Rocky Mountains. The major features are the aspen-covered lower slopes of the Rocky Mountain Foothills and the expanses of agricultural land on the plain.

Zone L is in southeastern British Columbia and is composed of the Rocky Mountains, Rocky Mountain Trench, and Columbia Mountains. The landscape consists of low, rolling foothills with predominantly aspen tree cover and barren or thinly forested (with conifers) peaks and ridges.

Zone M is in southeastern Alberta, east of the city of Calgary. The Alberta Plain produces a landscape of rolling terrain, which has a carpet-like, continuous grass cover, and is cut by rugged coulees. Some of the area is used for agriculture.

Zone N is in southwestern Saskatchewan, on the Saskatchewan Plain. The landscape features rolling terrain with carpet-like prairie grass cover or agriculture.

2.1.2.14 Air Quality

To assess the quality of the air along the route of the proposed pipeline, the following four factors need to be considered: the types of pollutants; the sources of pollution; effects of climate, micrometeorology, and topography; and the distribution of these factors along the route.

Types of Pollutants

The substances regarded as pollutants that are of principal interest in assessing air quality are carbon monoxide (CO), sulfur oxides (SO_x), nitrogen oxides (NO_x), hydrocarbons, photochemical oxidants, and particulate matter, generally dust and artificially produced solid matter. In some situations, including one of concern here, condensed water particles may also be considered a pollutant.

Pollutants are usually measured in terms of mass per volume, and the normal unit of measurement is micrograms per cubic meter ($\mu g/m^3$); gaseous pollutants that occur normally in rather high concentrations, such as CO, are more conveniently measured in milligrams per cubic meter (mg/m^3). Another widely used unit of concentration is parts per million (ppm), which expresses the ratio of pollutant volume to air volume.

Sources of Pollution

There are both natural and artificial (man-made) sources of pollution, but most of the common sources in developed areas are man-made. Among the major sources of gaseous and particulate pollutants are power plants, heavy-industry plants, automotive traffic, urban residential concentrations, and agricultural fields. Man-caused forest fires and intentional fires for land clearing and trash disposal are other artificial sources. Natural sources include exposed areas of loose fine-grained soils and geologic materials subject to wind erosion; naturally caused forest fires; and volcanic eruptions.

In general, sulfur oxides and particulate matter are associated with power plants and heavy industry; carbon monoxide and hydrocarbons are associated with automotive traffic; and nitrogen oxides derive from nearly all artificial sources. Dust is associated primarily with rural sources, both natural and artificial.

Climatic and Topographic Effects

The dispersal or concentration of pollutants depend to considerable extent on factors of climate and micrometeorology, that is, local atmospheric conditions, and to some degree also on topographic setting. These conditions often determine the degree to which sources of pollution and the pollutants produced actually present a problem in the degradation of the environment. High winds for example disperse atmospheric pollutants to lower concentrations that are no longer objectionable, whereas long periods of calm permit the build-up of pollutants. Wind directions determine where concentrations of pollutants will occur with respect to the sources of pollution. Irregularities in topography can hamper the ability of the winds to act as dispersing agents by precluding the development of near-ground open wind paths, or can channel winds to produce good pollution dispersal.

A climatic feature typical of the Arctic and other cold regions that has an important bearing on air pollution is the ground-surface-based air temperature inversion that is caused by the negative radiation balance over the ground and especially over vast snow and ice surfaces present during a great part of the year. This feature is particularly prevalent on winter mornings. In this situation a mass of dense cold air, as much as several thousand feet thick, is trapped beneath an overlying layer of warm air, and very little mixing occurs. Thus, if pollutants are added to this stable mass of air they remain where they are and their concentrations build up to levels that may greatly exceed those that would develop under conditions of normal temperature gradients with concomitantly greater air-mixing and pollutant-dispersing possibilities.

Another pollution problem that is restricted largely to the high latitudes is the occurrence of ice fog, in which the principal pollutant is ice particles, although the presence of other pollutants, such as hydrocarbon nuclei, greatly enhance its formation. Ice fog causes a reduction in visibility by high concentrations of suspended ice particles formed by the condensation of water vapor onto hydrocarbon nuclei. The amount of water vapor that can be held in air decreases drastically as the temperature of the air decreases. Under sufficiently cold conditions almost any water vapor emitted into the air by the combustion of fuel, which also produces the hydrocarbon nuclei, will immediately form ice fog. In general, ice fog can occur at temperatures of -4° F, is increasingly likely to form with further reduction in temperature, and at -40° F it is almost certain to form. There will be increased ice fogs in the pipeline area as industrialization increases. Topographic settings such as river valleys or basins confined by surrounding mountains, common settings for human habitation, can greatly enhance the development and persistence of both temperature inversions and ice fog.

Distribution of Air Pollution Along the Proposed Route

The distribution of most types of significant air pollution correlates well with the degree of industrial development of an area. Most of the proposed pipeline across Canada lies in areas of relatively little development, even in the southern part of the route, and of essentially no development north of about 59° N latitude. Thus, for most of the route there are at present probably no severe air pollution problems of the type encountered in heavily industrialized areas of Canada and the United States. Air quality is generally good.

North of 59° N latitude the widely scattered settlements, such as Inuvik, Fort McPherson, Norman Wells, and Fort Simpson, probably do not produce pollutants in sufficient amounts to constitute an air pollution problem. The large distances between such places assures that areas between them are free of pollution.

South of 59° N latitude, where there are settlements and rural habitations near the proposed route in many places, large areas of agricultural production, and occasional industrial sites such as oil and gas producing fields, refineries, and processing plants, there are many more sources of pollution per unit area than to the north.

The types of pollution, such as ice fog, that are characteristic of the North become decreasingly significant southward along the proposed route, and are virtually absent in the southern parts. Temperature inversions are present in the Mackenzie valley from about one-half to two-thirds of the time during the winter months. Temperature inversions _per se_ of course do not produce pollution, but increase the likelihood that even the limited number of pollutants produced at a locality may at times reach significant levels. Temperatures suitable for ice fog formation occur along the Mackenzie valley between one-tenth and one-half of the time during the four most severe winter months. The present naturally occurring levels of ice fog would be greatly increased in the North by hydrocarbon and water vapor quantities that would have relatively insignificant effects in areas of warmer climate. Therefore pollutants in this area can have a relatively greater effect.

The pipeline corridor by-passes heavily industrialized areas and therefore will be in relatively non-polluted areas. The two largest cities that are in the general area are Edmonton (80 miles) and Calgary (13 miles). Both cities have an air monitoring program and testing has proven that they have an air quality problem. Edmonton has had 24-hour particulate samples of as high as 313 micrograms/meter^3 and an annual average of 107.8 micrograms/meter^3. Calgary has had 24-hour particulate samples as high as 438 micrograms/meter^3 and an annual average of 157.4 micrograms/meter^3. These values are above the limit of 100 micrograms/meter^3 which the EPA has set for the National Ambient Air Quality standard of the United States.

2.1.2.15 Environmental Noise

The existing environment of the proposed pipeline route can be characterized as being very quiet. Except for natural sounds or occasionally intruding aircraft, the environment has little noise.

Two important factors relate to environmental noise: (1) the ambient sound levels at the point where the noise emanates, and (2) the transmission properties of the atmosphere and terrain from source of the noise to its receiver.

Ambient Sound Levels

The proposed route passes through primarily undeveloped areas in the Yukon and Northwest Territories, where the population densities are 0.07 and 0.02 persons per square mile, respectively. It passes through Alberta, where population densities (in the census divisions) range from 1.05 to 92.85 persons per square mile, with a median and mean of 5.34 and 15.68, respectively. Since there is a correlation between population density and the day-night sound level (U.S. EPA, 1974), the existing sound levels along the route are predictably very low.

The background sound levels along the proposed route in the Yukon and Northwest Territories are probably in a range of from 20 to 30 dB (linear scale), values measured near Arctic Village, Alaska (population: 110) (Klein, 1973). The mid-point of this range, 25dB, is selected as representing the typical, existing ambient sound level along the Canadian segment of the proposed route, with the exception that stretches adjacent to the Mackenzie River may have higher sound levels due to the sound of the river. These levels have not been estimated. C-weighted ambient sound levels of 33 to 66 dB were measured near rivers in Alaska (McCourt et al., 1974 and Reynolds, 1974), but neither the distances at which these measurements were made nor the similarity between these rivers and the Mackenzie River is known.

The ambient sound levels of the portion of the pipeline route which passes through Alberta may be compared to the background A-weighted sound levels (L_{90}) of 21 to 28 dBA measured in Morton County, North Dakota and Murray County, Minnesota; these counties have population densities of 11 and 14 persons per square mile, respectively.

Temporarily higher sound levels may be caused by aircraft flights or by natural sounds, such as wind, animal locomotion and vocalizations, thunder, and rockslides (McCourt et al., 1974).

Transmission Properties

The ability of sound to propagate from a source to a distant receiver depends upon the micrometeorological conditions along the path of the sound. In a perfect medium, with neither absorption nor reflection, the sound level would decrease 6dB for every doubling of distance or 20dB for every tenfold increase in distance. For example, a sound level of 80dB(A) measured at 100 feet from a source, would be 74dB(A) at 200 feet and 60dB(A) at 1,000 feet. In the air, the micrometeorological and ground conditions will cause what is called "excess attenuation," so that the sound will diminish more rapidly than 6dB per doubling of distance. These conditions are: (1) temperature gradients; (2) wind gradients; (3) wind direction; (4) humidity; (5) surface growth such as grass or trees; and (6) ground-level changes.

Wind creates a shadow zone upwind of the source where the sound may attenuate up to 26dB per distance doubling and concentrates sound downwind where it may attenuate at 9dB per distance doubling. In other parts of the proposed pipeline, there are farmlands and tree groupings which would have a greater effect on sound propagation than wind. Large stands of mature trees can be expected to provide an excess attenuation of about 5-7dB provided the stand is 40-50 feet high and 100-200 feet in depth and the receiver is 200-400 feet behind the stand.

The condition for attenuation is assumed to be one with no wind, with propagation over grass covered level fields for peak frequencies near 100Hz. For this case the total attenuation starting at 100 feet is expected to be as shown on the next page.

Distance, Feet	100	200	400	800	1,000	2,000	4,000
Attenuation, dB	0	6	13	19	23	32	44

The topography along most all of the proposed route is dominated by slopes that are nearly flat to very gentle, so that little shadowing is afforded. Exceptions occur primarily at river crossings and along the Kingsgate Delivery Line where the route crosses mountain ranges. In these areas, attenuation, in excess of that estimated above, will occur.

REFERENCES

American Ornithologists Union, 1957, Check-list of North American birds (5th ed.): Port City Press, Baltimore, Md., 691 p.

_______ 1973, Thirty-second supplement to the A. O. U. check-list of North American birds: Auk 90(2):411-419.

Aquatic-Environments Limited, 1974, Fisheries research associated with proposed gas pipeline routes in Alaska, Yukon, and Northwest Territories: Biological Report Series - Volume 15.

Banfield, A. W. F., 1974, The mammals of Canada: Univ. of Toronto Press, 438 p.

Bliss, L. C., and Peterson, E. B., 1973, The ecological impact of northern petroleum development. Paper No. 6, 5th Int. Congr. "Arctic Oil and Gas: Problems and Possibilities." Fondation d'Etudes Nordiques, LeHavre. 26 p.

Bliss, L. C., Courtin, G. M., Pattie, D. L., Riewe, R. R., Whitfield, D. W. A., and Widden, P., 1973, Arctic tundra ecosystems: Ann. Rev. Ecol. and Syst. 4:359-399.

Bostock, H. S., 1970, Physiographic subdivisions of Canada, chap. 2, in Douglas, R. J. W., (ed.), Geology and economic minerals of Canada (5th ed.): Canada Geol. Survey Econ. Geology Rept. 1, p. 9-30.

Bowser, W. E., Kjearsgaard, A. A., Peters, T. W., and Wells, R. E. 1962 Soil Survey of the Edmonton Sheet (83-H). University of Alberta Bulletin No. SS-4, 66 p., with map, scale 1:126,720.

Bowser, W. E. and Peters, T. W. 1951. Soil Survey of Red Deer Sheet. University of Alberta Bulletin No. 51, 86 p., with map, scale 1:190,080.

Boydell, A. N., and Rutter, N. W., 1973, Surficial geology and geomorphology of Mackenzie Valley Transportation Corridor (southern part): Canada Geol. Survey, Dept. Energy, Mines and Resources open-file report 189, 2 maps, scale 1:1,000,000.

Brandon, L. W., 1965, Ground water hydrology and water supply in the District of Mackenzie, Yukon Territory, and adjoining parts of British Columbia: Canada Geol. Survey Paper 64-39, 102 p.

Brown, I. C., 1970, Ground water geology, in Douglas, R. J. W., (ed.), Geology and economic minerals of Canada: Canada Geol. Survey Econ. Geology Rept. 1, p. 767-791.

Brown, R. J. E., 1967, Permafrost in Canada: Division of Building Research, National Research Council (NRC 9769) and Canada Geol. Survey Map 1246A, scale 1:7,603,200.

Brunskill, G. J., Rosenberg, D. M., Snow, N. B., Vascotto, G. L., and Wagemann, R., 1973a, Ecological studies of aquatic systems in the Mackenzie-Porcupine drainages in relation to proposed pipeline and highway developments: Environmental-Social Comm. Northern Pipelines, Task Force on Northern Oil Devel. Rept. 73-40 (v. 1), Info. Canada Cat. no. R72-10073/1-1, 131 p.

____1973b, Ecological studies of aquatic systems in the Mackenzie-Porcupine drainages in relation to proposed pipeline and highway developments, Volume II, Appendices: Environmental-Social Comm. Northern Pipelines, Task Force on Northern Oil Devel. Rept. 73-41 (v. 2), Info. Canada Cat. no. R72-10073/1-2, 345 p.

Bryan, J. E., 1973, The influence of pipeline development on freshwater fishery resources of northern Yukon Territory, aspects of research conducted in 1971 and 1972: Environmental-Social Comm. Northern Pipelines, Task Force on Northern Oil Devel. Rept. 73-6, Info. Canada Cat. no. R72-9773, 63 p.

Bryan, J. E., Walker, C. E., Kendel, R. E., and Elson, M. S., 1973, Freshwater aquatic ecology in northern Yukon Territory, 1971: Environmental-Social Comm. Northern Pipelines, Task Force on Northern Oil Devel. Rept. 73-21, Info. Canada Cat. no. R57-3/1973, 64 p.

Butters, T.H., 1972, Report of the N.W.T. Council Task Force on Housing: Department of Information, Yellowknife, N.W.T.

Canada Geological Survey, 1963, Geology, Yukon Territory and Northwest Territories: Canada Geol. Survey Map 30-1963, 1 sheet, scale 1:3,000,000.

Canada Geological Survey, 1969, Geological map of Canada: Canada Geol. Survey Map 1250A, 1 sheet, scale 1:5,000,000.

Canadian Arctic Gas Pipeline Limited, 1974a, Location, design and capacity of facilities (section 8) and connecting pipeline facilities (section 9): an exhibit in support of applications to the Department of Indian Affairs and Northern Development of Canada for authorization to use land and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, chapters individually paginated.

Canadian Arctic Gas Pipeline Limited, 1974b, Construction plan (section 13.a) and Operations and maintenance plans (section 13.b): an exhibit in support of applications to the Department of Indian Affairs and Northern Development of the Government of Canada for authorization to use land and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, chapters individually paginated.

Canadian Arctic Gas Pipeline Limited, 1974c, Regional socio-economic impact statement (section 14.c): an exhibit in support of applications to the Department of Indian Affairs and Northern Development of the Governemnt of Canada for authorization to use land and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, 40 p. and appendices A and B.

Canadian Arctic Gas Pipeline Limited, 1974d, Environmental statement, Canada-north of the 60th parallel (section 14.d N): an exhibit in support of applications to the Department of Indian Affairs and Northern Development of the Government of Canada for authorization to use land and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, chapters individually paginated.

Canadian Arctic Gas Pipeline Limited, 1974e, Environmental statement, Canada-south of the 60th parallel (section 14.d S): an exhibit in support of applications to the Department of Indian Affairs and Northern Development of the Government of Canada for authorization to use land and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, chapters individually paginated.

Canadian Arctic Gas Pipeline Limited, 1974f, Alignment sheets, pipeline route in Canada north of 60° latitude: prepared by Northern Engineering Services Company Limited, unpaged.

Canadian Arctic Gas Pipeline Limited, 1974g, Alignment sheets, pipeline route in Canada, south of 60° latitude: prepared by Northern Engineering Services Company Limited, unpaged.

Canadian Arctic Gas Pipeline Limited, 1975a, Amendments to alignment sheets (section 8.a.3, pipeline routing in the vicinity of Fort Simpson), and design drawings (section 8.b.3, for certain major river crossings), unpaged.

Canadian Arctic Gas Pipeline Limited, 1975b, Gas Supply Areas (section 4), Gas Supply Reserves (section 5), Gas Supply Deliverability (section 6), Supply Deliverability (section 7): exhibits in support of an application to the National Energy Board of Canada for a Certificate of Public Convenience and Necessity authorizing the construction of pipeline facilities, chapters individually paginated.

Canadian National Committee, 1974, Permafrost hydrology-Proceedings of workshop seminar, 1974: Ottawa, The Secretariat, Canadian National Comm. International Hydrologic Decade, Dept. of the Environment Canada, 1974, 102 p.

Coulson, A., and Adamcyk, R. J., 1969, The effects of the W.A.C. Bennett Dam on downstream levels and flows: Inland Waters Branch Tech. Bull. 18, 9 p.

Crampton, C. B. 1973. The distribution and possible genesis of some organic terrain patterns in the Southern Mackenzie River Valley. Canadian Journal of Earth Sciences, Vol. 10, No. 3, p. 432-438.

Dabbs, D. L., Friesen, W., and Mitchell, S., 1974, Pipeline revegetation: Arctic Gas Biol. Rep. Ser. Vol. 2 Canadian Arctic Gas Study Ltd., Calgary, Alberta.

Davies, K.F., 1974, Hydrometric data summary, Mackenzie River basin, 1973: Environmental-Social Comm. Northern Pipelines, Task Force on Northern Oil Devel. Rept. 74-8, Info. Canada Cat. no. R57-6/1973, 84 p.

Day, J. H. 1966. Reconnaissance Soil Survey of the Liard River Valley. Research Branch, Canada Department of Agriculture, 71 p., with map, scale 1:250,000.

Day, J. H. 1968. Soils of the Upper Mackenzie River Area. Research Branch, Canada Department of Agriculture, 77 p., with maps (2 Sheets), scale 1:250,000.

Day, J. H. and Rice, H. M. 1964. The characteristics of some permafrost soils in the Mackenzie Valley, N.W.T. Arctic, Vol. 17, No. 4., p. 223-236.

de Wit, R., Granberg, E. C., Richards, W. B., and Richmond, W. D., 1973, Tathlina area, southern district of Mackenzie, p. 187-212, in McCrossan, R. G. (ed.), Future Petroleum Province of Canada: Canadian Soc. Petroleum Geologists Mem. 1,720 p.

Douglas, R. J. W. (ed.), 1970, Geology and economic minerals of Canada: Canada Geol. Survey Econ. Geology Rept. 1,838 p.

Dryden, R. L., Sutherland, B. G., and Stein, J. N., 1973, An evaluation of the fish resources of the Mackenzie River Valley as related to pipeline development v. 2: Environmental-Social Comm., Northern Pipelines, Task Force on Northern Oil Devel., Rept. 73-2, Info. Canada Cat. no. Fs37-1973/1-2, 176 p.

Dumanski, J., Macyk, T. M., Veauvy, C. F., and Lindsay, J. D. 1972. Soil Survey and Land Evaluation of the Hinton-Edson Area, Alberta. University of Alberta Bulletin No. SS -14, 119 p., with map, scale 1:126,720.

Environment Protection Board, 1974a, Environmental impact assessment of the portion of the Mackenzie gas pipeline from Alaska to Alberta; Vol. III - Environmental Atlas: sponsored by Canadian Arctic Gas Study Ltd.

Environment Protection Board, 1974b, Enviornmental impact assessment of the portion of the Mackenzie gas pipeline from Alaska to Alberta, Vol. IV - Research reports; sponsored by Canadian Arctic Gas Study Ltd., 308 p.

Ferrians, O. J., Jr., compiler, 1965, Permafrost map of Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-445, scale 1:2,500,000.

Ferrians, O. J., Jr., Kachadoorian, Reuben, and Greene, G. W., 1969, Permafrost and related engineering problems in Alaska: U.S. Geol. Survey Prof. Paper 678, 37 p.

Ferrians, O. J., Jr., Kachadoorian, Reuben, Cobb, E. H., and Page, Robert, 1972, Physiography and geology, in Final environmental impact statement, proposed trans-Alaska pipeline, v. 2, Environmental setting of the proposed trans-Alaska pipeline system: U.S. Dept. Interior.

Fleming, R. W., Spencer, G. S., and Banks, D. C., 1970. Empirical study of behavior or clay shale slopes, I and II: U.S. Army Eng.

Nuçle Cratering Group, Tech. Rept. 15, Livermore, California, 421 p.

Fremlin, G. (Ed.) 1974. The National Atlas of Canada. The Macmillan Company of Canada Limited, Ottawa, 254 p.

Gemini North Ltd., 1974a, Social and economic impact of proposed Arctic Gas pipeline in northern Canada: Book 1, vols. I and II (portion), sponsored by Canadian Arctic Gas Pipeline Limited, volumes individually paginated.

Gemini North Ltd., 1974b, Social and economic impact of proposed Arctic Gas pipeline in northern Canada: Book 2, vols. II (portion), III, and IV, sponsored by Canadian Arctic Gas Pipeline Limited, volumes individually paginated.

Gemini North Ltd., 1974c, Social and Economic impact of proposed Arctic Gas pipeline in northern Canada: Book 3, vols. V and VI, sponsored by Canadian Arctic Gas Pipeline Ltd., volumes individually paginated.

Gemini North Ltd., 1974d, Social and economic impact of proposed Arctic Gas Pipeline in northern Canada: Book 4, vol. VII, sponsored by Canadian Arctic Gas Pipeline Ltd., 106 p.

Gilbert, D. L. F., 1973, Anderson Plain, northern district of Mackenzie, p. 213-244, in McCrossan, R. G. (ed.), Future Petroleum Province of Canada: Canadian Soc. Petroleum Geologists Mem. 1,720 p.

Godfrey, W. Earl, 1966, The birds of Canada: Nat'l. Mus. of Canada Bull. 208, Biological Series No. 75, Ottawa, 428, p.

Government of Alberta, 1969, Atlas of Alberta: Edmonton, Alberta Univ. Press, 162 p.

Grainge, J.W., Edwards, R., Heuchert, and Shaw, J.W., 1973. Management of waste from arctic and sub-artic work camps: Environmental-Social Committee, Task Force on Northern Oil Development, Report No. 73-19, 61 p.

Hall, E. R., and Kelson, K. R., 1959, The mammals of North America: Ronald Press, New York, 2 volumes.

Hanley, P. T., and Hughes, O. L., 1973, Surficial geology and geomorphology of Mackenzie Valley Transportation Corridor (central part): Canada Geol. Survey, Dept. Energy, Mines and Resources open-file report 189, 2 maps, scale 1:1,000,000.

Hardy, R. M., Brooker, E. W., and Curtis, W. E., 1962, Landslides in over-consolidated clays: Eng. Jour., vol. 45, no. 6, p. 81-89.

Heginbottom, J. A., 1973, Some effects of surface disturbance on the permafrost active layer at Inuvik, N.W.T.: Environ.-Social Comm. Northern Pipelines, Task Force on Northern Oil Development, Ottawa, Ontario. Rep. 73-16.

Henderson, E. P., 1959. Surficial geology of Sturgeon Lake map-area, Alberta: Canada Geol. Survey Mem. 303, 108 p.

Hernandez, H., 1973, Natural plant recolonization of surficial disturbances, Tuktoyaktuk Peninsula region, N.W.T.: Can. J. Bot. 51:2177-2196.

________ 1974, Possible effects on vegetation of the proposed gas pipeline from Prudhoe Bay, Alaska and the Mackenzie Delta to Alberta. P. 37-68 in Research Reports, Vol. IV, Environmental impact assessment of the portion of the Mackenzie gas pipeline from Alaska to Alberta: Environment Protection Board, Winnipeg.

Hettinger, Loren, Janz, Arnold, and Wein, R. W., 1973, Vegetation of the northern Yukon Territory: Biol. Rept. Ser., Canadian Arctic Gas Study Limited prepared by Northern Engineering Services Limited, v. 1, 171 p.

Howitt, Frank, and Clegg, M. W., 1970, Permafrost in Prudhoe Bay Field; geology and physical characterists (abs.): Am. Assoc. Petroleum Geologists Bull, v. 54, no. 12, p. 2487.

Inland Waters Directorate, 1973, Index of water quality stations, 1st ed.: Ottawa, Water Quality Branch, Dept. of the Environment Canada, 100 p.

Jacobson, J. O., 1974, Potential impact of the Mackenzie gas pipeline on bird populations in the Yukon and Northwest Territories, Chapt. 6 in Research Reports, Vol. IV, Environmental impact assessment of the portion of the Mackenzie gas pipeline from Alaska to Alberta: Environment Protection Board, Winnipeg.

Janz, Arnold, 1972, Soil Survey in the Mackenzie Delta region in Bliss, L. C., and Wein, R. W., (eds.), Botanical studies of natural and man modified habitats in the eastern Mackenzie Delta region and the Arctic Islands: a report prepared under contract for the Arctic Land Use Research Program, Northern Economic Development Branch, Department of Indian Affairs and Northern Development, v. 71-72-14, p. 47-68.

________ 1973, Topographic influence on soil and plant nutrients in the Low Arctic. Pages 27-44 in Bliss, L. C., (ed.), Botanical studies of natural and man-modified habitats in the Mackenzie Valley, eastern Mackenzie Delta region and the Arctic Islands: ALUR 72-73-14. Dept. Indian Affairs and Northern Development, Ottawa.

Joint Federal-State Land Use Planning Commission for Alaska, 1973, Major Ecosystems of Alaska: U.S. Geol. Survey, Washington, D. C.

Johnston, G. H. and Brown, R. J. E. 1964. Some observations on permafrost distribution at a lake in the Mackenzie Delta, N.W.T., Canada. Arctic, Vol. 17, No. 3, p. 163-175.

Johnston, W. A., Wickenden, R. T. D., and Weir, J. D., 1948, Preliminary map, surface deposits, southern Saskatchewan: Canada Geol. Survey Paper 48-18, 2 sheets, scale 1:380,160.

Kathol, C. P., and McPherson, R. A., 1974, Susceptibility of geologic deposits to erosion in the House Mountain area, Alberta: Alberta Resource Report 74-5, 33 p.

Kelley, C. C. and Sprout, P. N. (undated). Soil Survey of the Upper Kootenay and Elk River Basins in the East Kootenay District of British Columbia. Report No. 5 of the British Columbia Soil Survey, 99 p., with maps (5 sheets), scale 1:63,360.

Klein, D. R. 1973. "The reaction of some northern mammals to aircraft disturbances," 11th International Congress of Game Biologists. Stockholm, Sweden.

Konopasek, P. (undated), Water quality of the Athabasca River: Division of Pollution, Dept. of the Environment, 1971-72, 17 p.

Lachenbruch, A. H., 1970, Some estimates of the thermal effects of a heated pipeline in permafrost: U.S. Geol. Survey Circ. 632, 23 p.

Lavkulich, L. M., (ed.), 1972, Soils, vegetation and landforms of the Fort Simpson Area, N.W.T.: a report prepared under contract for the Arctic Land Use Research Program, Northern Economic Development Branch, Department of Indian Affairs and Northern Development, v. 71-72-51, 257 p.

Leblanc, G. and Wetmiller, R. J., 1974, An evaluation of seismological data available for the Yukon Territory and the Mackenzie Valley: Canadian Jour. Earth Sci. 11, p. 1435-1454.

Lindsay, J. D., Pawluk, S., and Odynsky, W., 1958, Exploratory soil survey of Alberta, Map Sheets 84-D (north half), 84-E, 84-F, and 84-G, with an appendix by L. A. Bayrock: Research Council of Alberta, Prelim. Soil Survey Rept. 59-1, 48 p.

____ 1959, Exploratory soil survey of Alberta, Map Sheets 84-J, 84-K, and 84-L, with an appendix by L. A. Bayrock: Research Council of Alberta, Prelim. Soil Survey Rept. 60-1, 49 p.

____ 1960, Exploratory soil survey of Alberta, Map Sheets 84-M, 84-N, and 84-O, with an appendix by L. A. Bayrock: Research Council of Alberta, Prelim. Soil Survey Rept. 61-1, 43 p.

Lindsay, J. D., Wynnyk, A., and Odynsky, W., 1963, Exploratory Soil Survey of Alberta, Map Sheets 83-L, 83-K, 83-F, and 83-J: Research Council of Alberta, Prelim. Soil Survey Rept. 64-2, 53 p.

Little, H. W., Belyea, H. R., Stott, D. F., Latour, B. A., and Douglas, R. J. W., 1970, Economic minerals of western Canada, in Douglas, R. J. W., (ed.), Geology and economic minerals of Canada: Canada Geol. Survey Econ. Geology Rept. 1, Chapt. 9, p. 490-546.

MacDonald, B. C., and Lewis, C. P., 1973, Geomorphic and sedimentologic processes of rivers and coast, Yukon coastal plain: Environmental-Social Comm. Northern Pipelines, Task Force on Northern Oil Devel., Rept. 73-39, Info. Canada Cat. no. R72-12173, 245 p.

Mackay, J. R., 1967, Permafrost depths, lower Mackenzie valley, Northwest Territories: Arctic, v. 20, no. 1, p. 21-26.

Mackay, W. H., and North, Fik., 1974, Methods of estimating undiscovered oil reserves: Paper presented at the Stanford Conference, August 21, 1974.

Masuda, A., 1971, Pollution survey summary, North Saskatchewan River, 1970-1971: Province of Alberta, Dept. of the Environment, Div. of Pollution Control, 29 p., 3 appendices.

Matheson, D. S., and Thomson, S., 1973, Geological implications of valley rebound: Canadian Jour. Earth Sci., v. 10, no. 6, p. 961-978.

McCart, P. J., 1974, Late winter surveys in lakes and streams in Canada and Alaska along the gas pipeline route under consideration by Canadian Arctic Gas Study, Ltc., 1972-73, Chap. 1 in McCart, P. J., (ed.), Fisheries research associated with proposed gas pipeline route in Alaska, Yukon and Northwest Territories: Arctic Gas Biological Rept. Ser. v. 15, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co., 183 p. and maps. (Chapters individually paginated.)

Mc Court, K. H., Feist, J. D., Doll, D., and Russell, J. J. 1974. Disturbance Studies of Caribou and Other Mammals in the Yukon and Alaska, 1972 Artic Gas Biological Report Series, Vol. 5, Canadian Arctic Gas Study Ltd. and Alaskan Arctic Gas Study Co.

McCrossan, R. G., and Porter, J. W., 1973, The geology and petroleum potential of the Canadian sedimentary basins--a synthesis, p. 589-720, in McCrossan, R. G., (ed.), Future Petroleum Provinces of Canada: Canadian Soc. Petroleum Geologists. Mem. 1, 720 p.

Meyboom, P., 1967, Interior Plains hydrogeological region, Chap. 6 in Brown, I. C., (ed.), Ground water in Canada: Canadian Geol. Survey, Economic Geology Rept. 24, p. 131-158.

Millar, J. F. V., 1974, Proposal for archaeological salvage, pipeline corridor, Yukon and Northwest Territories: Archaeological Supplement to the Biological Report Series, Canadian Arctic Gas Study, Ltd., 2d ed., unpaged.

Mitchell, J., Moss, H. C., and Clayton, J. S. 1947. Soil survey of Southern Saskatchewan from Township 1 to 48 inclusive. University of Saskatchewan, Soil Survey Report No. 12, 259 p.

Moss, H. C. 1965. A Guide to Understanding Saskatchewan Soils. University of Saskatchewan, Extension Publication 175, 79 p.

Moss, H. C. and Clayton, J. S. 1967. Soil Map of Saskatchewan, scale 1:2,500,000. Atlas of Saskatchewan, University of Saskatchewan.

Muller, S. W., 1947, Permafrost or permanently frozen ground and related engineering problems: Edwards Bros., Ann Arbor, Mich., 231 p.

Mutch, R. A., and McCart, P. J., 1974, Springs within the northern Yukon drainage system (Beaufort Sea drainage), Chap. 9 in McCart, P. J., (ed.), Fisheries research associated with proposed gas pipeline route in Alaska, Yukon and Northwest Territories: Arctic Gas Biological Rept. Ser. v. 15, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co., 30 p. (Chapters individually paginated.)

Nauman, J. W., and Kernodle, D. R., 1973, Field water-quality information along the proposed trans-Alaska pipeline corridor, September 1970 through September 1972: U.S. Geol. Survey basic-data rept., 22 p.

Nielsen, G. L., 1969, Groundwater inventory, South Saskatchewan drainage basin: Province of Alberta, Dept. of the Environment, Earth Sciences and Licensing Div., July 1969.

Nielsen, G. L., and Lorberg, E., 1971, Ground water inventory of southern Alberta (south of 54 degrees N. latitude): Province of Alberta, Dept. of the Environment, 48 p.

Odynsky, W. and Newton, J. D. 1950. Soil Survey of the Rycroft and Watino Sheets. University of Alberta Bulletin No. 53, 84 p., with map, scale 1:190,080.

Odynsky, W., Wynnyk, A., and Newton, J. D. 1952. Reconnaissance Soil Survey of the High Prairie and McLennan Sheets. University of Alberta Bulletin No. 59, 112 p., with map, scale 1:190,080.

Odynsky. W., Wynnyk, A., and Newton, J. D. 1956. Reconnaissance Soil Survey of the Grand Prairie and Sturgeon Lake Sheets. University of Alberta Bulletin No. 60, 111p., with map, scale 1:190,080.

Paetz, Martin, and Nelson, J., 1970, The fishes of Alberta: Royal Printer, Edmonton, 282 p.

Pawluk, S., and Bayrock, L. A., 1969, Some characteristics and physical properties of Alberta tills: Research Council of Alberta Bulletin 26, 72 p.

Peters, T. W. and Bowser, W. E. 1959. Soil Survey of Rocky Mountain House Sheet. University of Alberta Bulletin No. 22-1, 50 p., with map, scale 1:126,720.

Pettapiece, W. W. 1975. Soils of the Subarctic in the Lower Mackenzie Basin. Arctic, Vol. 28, No. 1, p. 35-53.

Pihlainen, J. A., and Johnston, G. H., 1963, Guide to a field description of permafrost for engineering purposes: Canada Natl. Research Council Tech. Mem. 79, 21 p.

Pipeline Application Assessment Group, 1974, Mackenzie Valley pipeline assessment; Environmental and socio-economic effects of the proposed Canadian Arctic Gas Pipeline on the Northwest Territories and Yukon: issued under the authority of the Minister of Indian Affairs and Northern Development, Ottawa, 442 p.

Prest, V. K., 1970, Quaternary geology of Canada, chap. 12 in Douglas, R. J. W., (ed.), Geology and economic minerals of Canada (5th ed.): Canada Geol. Survey Econ. Geology Rept. 1, p. 675-764.

Prest, V. K., Grant, D. R., and Rampton, V. N., compilers, 1968, Glacial map of Canada: Canada Geol. Survey Map 1253A, scale 1:5,000,000.

Price, R. A., 1962, Fernie map-area, east half, Alberta and British Columbia, 82 G, E 1/2: Canada Geol. Survey Paper 61-24, 65 p.

Rampton, V. N., 1972, Surficial geology and landforms, Aklavik (107B) (E 1/2): Canada Geol. Survey Open-file report OF 119, scale 1:125,000.

________ 1974, Surficial geology and landforms for parts of Aklavik (107B), Blow River (117A), Demarcation Point (117C), Herschel Island (117D): Canada Geol. Survey open-file report 191.

Reeder, S. W., Hitchon, Brian, and Levinson, A. A., 1972, Hydrogeochemistry of the surface waters of the Mackenzie River drainage basin, Canada - I, Factors controlling inorganic composition: Geochim. et Cosmochim. Acta, v. 36, p. 825-865.

Reeder, S. W. and Odynsky, W. 1969. Reconnaissance Soil Survey of the Hotchkiss and Keg River Area. University of Alberta Bulletin No. SS-9, 90 p., with map, scale 1:190,080.

Reid, David E., 1974, Vegetation of the Mackenzie Valley - Part One: Biol. Rept. Ser., Canadian Arctic Gas Study Limited, prepared by Northern Engineering Services Limited, v. 3, 145 p.

Reynolds, P. C. 1974. "The effects of simulated compressor station sounds on Dall sheep using mineral licks on the Brooks Range, Alaska," The Reaction of Some Mammals to Aircraft and Compressor Station Noise Disturbances, edited by R. D. Jakimchuk, Artic Gas Biological Report Series, Vol. 23, Canadian Arctic Gas Study Ltd. and Alaskan Artic Gas Study Co.

Richards, J. H., and Fung, K. I., 1969, Atlas of Saskatchewan: Saskatoon, Saskatchewan, Saskatchewan Univ., 236 p.

Roed, M. A., 1970, Surficial geology--Edson, NTS 83F: Alberta Research Council Map 33, scale 1:250,000.

Rowe, J. S., 1972, Forest regions of Canada: Can. For. Serv. Publ. 1300. Dept. Environ., Ottawa. 172 p.

Rudkin, R. A., 1974a, b, Petroleum potential of Arctic Canada: Pt. I and II, Oil and Gas Journal, v. 72, nos. 9 and 10, p. 136-137, p. 149-151, March 4 and 11, 1974.

Rutherford, R. L., 1930, Geology and water resources in parts of the Peace River and Grande Prairie Districts, Alberta: Alberta Research Council Rept. 21, 68 p.

St. Onge, D. A., 1967, Surficial geology--Iosegun Lake (east half), Alberta: Canada Geol. Survey, Dept. Energy, Mines and Resources Map 15-1966, scale 1:253,440.

Salt, W. R., and Wilk, W. L., 1958, Birds of Alberta, (2nd ed. revised): The Queen's Printer, Edmonton, 511 p.

Scheelar, M. D. and Macyk, T. M. 1972. Reconnaissance Soil Survey of the Mount Watt and Fort Vermilion Area. University of Alberta Bulletin No. SS-13, 51 p., with map, scale 1:190,080.

Scheelar, M. D. and Odynsky, W. 1968. Reconnaissance Soil Survey of the Grimshau and Notikewin Area. University of Alberta Bulletin No. SS-8, 80 p., with map, scale 1:190,080.

Scott, J. S., and Brooker, E. W., 1968, Geological and engineering aspects of Upper Cretaceous shales in Western Canada: Canada Geol. Survey Paper 66-37, 75 p.

Shewchuk, P. G., 1971, Pollution survey summary, South Saskatchewan River, 1970-1971: Province of Alberta, Dept. of the Environment, Div. of Pollution Control, 25 p., 1 appendix.

Soil Research Institute. 1972. Soils of Canada, scale 1:5,000,000. Canada Department of Agriculture.

Stalker, A. M., 1962, Surficial geology, Fernie (east half), Alberta and British Columbia: Canada Geol. Survey Prelim. Ser. Map 31-1961, scale 1:253,440.

______ 1965, Surficial geology, Bassano (Gleichen, east half), west of fourth meridian, Alberta: Canada Geol. Survey Prelim. Ser. Map 5-1965, scale 1:253,440.

______ 1973, Surficial geology of the Drumheller area, Alberta: Canada Geol. Survey Mem. 370, 122 p.

Stevens, A. E. and Milne, W. G., 1973, Seismic risk in the northern Yukon and adjacent areas; Task Force on Northern Oil Development, Rept. no 73-7, Dept. Energy, Mines and Resources, Ottawa, Canada, 27 p.

Stevens, A. E., Milne, W. G., Wetmiller, R. J., and Leblanc, G., 1973 Canadian Earthquakes - 1967: Seismol. Ser., Earth Phys. Br., No. 65, Ottawa, Canada, 65 p.

Stichling, W., 1974, Sediment loads in Canadian rivers: Inland Waters Directorate, Water Resources Branch Tech. Bull. 74, 27 p.

Strang, R. M., 1973, Studies of vegetation, landform and permafrost in the Mackenzie Valley: Some case histories of disturbance: Environ.-Social Comm. Northern Pipelines, Task Force on Northern Oil Development. Rep. 73-14. Ottawa, Ontario.

Tarnocai, C. 1973. Soils of the Mackenzie River Area. Environmental-Social Committee, Northern Pipelines, Task Force on Northern Oil Development, Report No. 73-26, 136 p.

Task Force on Northern Oil Development, 1973, Hydrologic aspects of northern pipeline development: Environmental-Social Comm., Northern Pipelines, Task Force on Northern Oil Devel., Rept. 73-3, Info. Canada, Cat. no. R27-172, 664 p.

Thomas, J. F. J., 1964, Surface water quality in major drainage basins and northern areas of Canada: Reprint from Jour. Am. Water Works Assoc., v. 56, no. 9, p. 1173-1193; Reprint Series No. 10, Inland Waters Branch, Dept. of Energy, Mines and Resources.

Thomson, S., and Hayley, D. W., 1975, The Little Smoky landslide: Canadian Geotech. Jour., vol. 12, no. 3, p. 379-392.

Twardy, A. G. and Lindsay, J. D. 1971. Reconnaissance Soil Survey of the Chip Lake Area. Univerisy of Alberta Bulletin No. SS-11, 71 p., with map, scale 1:126,720.

University of Alberta, Dominion Experimental Farms Service, Alberta Research Council and Department of Agriculture. 1945. Soil Zones of Alberta, scale 1:2,600,000.

U.S. Geol. Survey, 1974, Water resources data for Alaska, Pt. 1 - Surface water records, Pt. 2 - Water quality records: U.S. Dept. of the Interior, 299 p.

U.S. Environmental Protection Agency, 1974, Population Distribution of the United States as a function of outdoor noise levels: U.S. EPA Document 550/9-74-009.

van Everdingen, R. O., 1974, Ground water in permafrost regions of Canada, in Permafrost Hydrology--Proceedings of workshop seminar, 1974: Ottawa, The Secretariat, Canadian Natl. Comm., Internat. Hydrologic Decade, Canada Dept. of the Environment, 1974, p. 83-93.

Water Survey of Canada, 1968a, Sediment data for Canadian rivers, 1968: Inland Waters Directorate, Canada Dept. of Environment, 255 p.

____1968b, Sediment data for selected Canadian rivers, 1965: Inland Waters Branch, Dept. of Energy, Mines and Resources, 103 p.

____1969a, Sediment data for Canadian rivers, 1966: Inland Waters Branch, Dept. of Energy, Mines and Resources, 157 p.

____1969b, Sediment data for Canadian rivers, 1969: Inland Waters Directorate, Canada Dept. of the Environment, 261 p.

____1970a, Sediment data for Canadian rivers, 1967: Inland Waters Branch, Dept. of Energy, Mines and Resources.

____1970b, Water temperatures of selected streams in Alberta, Saskatchewan and the Northwest Territories: Dept. of Energy, Mines, and Resources, Inland Waters Branch, Calgary Dist.

____1972, Surface water data, Yukon Territory and Northwest Territories, 1971: Inland Waters Branch, Canada Dept. of the Environment, 50 p.

____1973, Surface water data, Yukon and Northwest Territories, 1972: Inland Waters Directorate, Canada Dept. of the Environment, 54 p.

____1974, Surface water data, Reference index, Canada, 1973: Inland Waters Directorate, Canada Dept. of the Environment, 262 p.

Wein, R. W., 1971, Report on a vegetation survey along the proposed gas pipeline route, Peel Plateau to Old Crow Mountains. Appendix III, Vegetation in Interim Report No. 1. Towards an environmental impact assessment of a gas pipeline from Prudhoe Bay, Alaska, to Alberta: Environment Protection Board, Winnipeg, Manitoba. 58 p.

________ 1972, Addendum to Appendix III, Vegetation in Interim Report No. 1. Towards an environmental impact assessment of a gas pipeline from Prudhoe Bay, Alaska, to Alberta: Environment Protection Board, Winnipeg, Manitoba. 12 p.

Wein, R. W. and Bliss, L. C., 1973, Biological Considerations for Construction in the Canadian Permafrost Region Paper No. 6, Mackenzie Delta region, p. 762-770, in Permafrost: The North American Contribution to the Second International Conference: National Academy of Sciences, Washington, D. C.

Williams, J. R., 1970, Ground water in the permafrost regions of Alaska: U.S. Geol. Survey Prof. Paper 696, 83 p.

Wyatt, F. A. 1935. Preliminary Soil Survey of the Peace River - High Prairie - Sturgeon Lake Area. Research Council of Alberta Report No. 31, 28 p., with map, scale 1:253,440.

Wyatt, F. A. 1939. Soil Survey of Lethbridge and Pincher Creek Sheets. University of Alberta Bulletin No. 32, 98 p., with map, scale 1:190.080.

Wyatt, F. A. and Newton, J. D. 1927. Soil Survey of Sounding Creek Sheet. University of Alberta Bulletin No. 16, 66 p., with map, scale 1:190,080.

Wyatt, F. A. and Newton, J. D. 1942. Soil Survey of Blackfoot and Calgary Sheets. University of Alberta Bulletin No. 39, 119 p., with map, scale 1:190,080.

Wyatt, F. A. and Newton, J. D. 1943. Soil Survey of Rosebud and Banff Sheets. University of Alberta Bulletin No. 40, 126 p. with map, scale 1:190.080.

Wyatt, F. A., Newton, J. D., and Mather, T. H. 1930. Soil Survey of St. Ann Sheet. University of Alberta Bulletin No. 20, 66 p., with map, scale 1:190,080.

Wyatt, F. A. and Younge, O. R. 1930. Preliminary soil Survey Adjacent to the Peace River, Alberta, West of Dunvegan. Research Council of Alberta Report No. 23, 33 p., with map, scale 1:253,440.

Younkin, W. E., 1972, Revegetation studies of disturbances in the Mackenzie Delta region. Pages 175-229 in Bliss, L. C., and Wein, R. W., (eds.), Botanical studies of natural and man-modified habitats in the eastern Mackenzie Delta Region and the Arctic Islands: ALUR 71-72-14. Dept. Indian Affairs and Northern Development, Ottawa.

________ 1973, Autecology studies of native species potentially useful for vegetation, Tuktoyaktuk region, N.W.T. Pages 45-76 in Bliss, L. C., (ed.), Botanical studies of natural and man-modified habitats in the Mackenzie Valley, eastern Mackenzie Delta region and the Arctic Islands: ALUR 72-73-14. Dept. Indian Affairs and Northern Development, Ottawa.

Zoltai, S. C. and Pettapiece, W. W. 1973. Studies of Vegetation, Landform and Permafrost in the Mackenzie Valley: Terrain, Vegetation and Permafrost Relationships in the Northern Part of the Mackenzie Valley and Northern Yukon. Environmental-Social Committee, Northern Pipelines, Task Force on Northern Oil Development, Report No. 73-4, 105 p.

Zoltai, S. C. and Tarnocai, C. 1974. Soils and Vegetation of Hummocky Terrain. Environmental-Social Committee, Northern Pipelines, Task Force on Northern Oil Development.

3 ENVIRONMENTAL IMPACT OF THE PROPOSED ACTION

3.1 ARCTIC GAS PIPELINE PROJECT

3.1.2 Canadian Pipeline

Introduction and Summary

There will be no significant impact on regional climate; however, climate will have a major impact on the construction and operation of the pipeline in the Arctic and the Subarctic. The cold air temperature, combined with winds and the long, winter darkness will cause extreme stresses on personnel, materials, equipment, and machines.

Topography, Geology, and Soils

The major unavoidable effect on topography would be the excavation of at least 108 borrow pits averaging about 14 acres each. In addition, plans call for a nearly continuous berm of soil (several feet high and about 5 feet wide) directly over the pipe.

A buried chilled pipeline poses special geologic problems such as heaving of the pipe and disruption of shallow ground-water movement. It has not been demonstrated that the integrity of the pipeline can be maintained everywhere in the permafrost area. Thawing of ice-rich, fine-grained permafrost materials could locally result in serious impacts such as soil liquefaction, slope instability, differential settlement of the ground surface, disruption of drainage, and accelerated erosion along as much as 800 miles of the route north of about Milepost 600 on the Main Line and on the Supply Lines. Approximately 30 million cubic yards of construction material from borrow pits and quarries will be required for construction of the pipeline system.

Adverse effects on agricultural soils would be minor except on the right-of-way of the proposed pipeline, permanent roads, temporary access roads, and other graded or filled areas. These effects would be significant only in areas of agricultural development, mostly south of Milepost 1100 on the Main Line and on the Delivery Lines.

Water Resources

Excavation of materials and the placement of fill during construction of the proposed pipeline will alter numerous natural drainage channels. Erosion could be accelerated because of the potential for increased velocities and concentrated flows, steepened terrain slopes, soil disturbances and vegetation modification. Changes in the subsurface drainage caused by pipeline construction, soil compaction, or the frozen annulus around a chilled pipe could result in conversion of subsurface flow to surface flow and thus increase erosion. Changes in the form of drainage could alter the freeze-thaw, wet-dry, liquefaction, or other characteristics of soils leading to new or accelerated mass movement. A principal potential impact of such soil movements would be the disfiguration of the landscape and a decrease in the quality of water.

The proposed pipeline alignment would cross numerous streams and flood plains. Where the pipeline is buried at stream crossings, scour might expose the pipe and cause damage and even rupture. Along the northern one-third of the route, the formation of river icings (aufeis) could affect the integrity of aboveground structures as well as cause unpredictable effects on depths of riverbed scour.

The natural quality of water in streams or lakes would be impaired where construction-related activities, including the removal of vegetation, sand and gravel mining, and grading and filling for roads or camp buildings, would add particulate matter. Adverse effects of sedimentation could largely be controlled during the life of the project but would be unavoidable during construction.

Contamination of streams and lakes by deliberate or accidental discharge of toxic chemicals would be a long-term, continuing threat to water quality and plant and animal populations both in freshwater and marine environments. The effects could be critical along major waterways but cannot be quantified as they would depend for the most part on the incidence of accidental spillage and leakage of fuel oil and other toxic materials.

Vegetation

Unavoidable effects of the proposed pipeline on vegetation would be relatively insignificant in terms of the total resource of plant communities. Losses of vegetation would occur on all land areas occupied by permanent roads, airstrips, compressor stations, wharves, stockpiles, borrow pits and other facilities. On the pipeline right-of-way clearing of trees would cause a loss of forest productivity. In the long term, following abandonment of the proposed project, all vegetation should recover, although scars would be visible for many decades.

Throughout the lifetime of the proposed project, an apparently intractable problem in permafrost zones would be unscheduled maintenance operations requiring movement of heavy machinery over land to meet emergency situations such as pipeline ruptures or fires. Such operations could cause more damage to vegetation and terrain than would the initial construction of a pipeline. The adverse effects would be especially severe in the Herbaceous Coastal Tundra where soils are ice-rich, recovery of stable terrain and vegetation is slow, and scars on the landscape are highly visible and long enduring.

Wildlife

The pipeline along the proposed route should have few unavoidable adverse effects on fish populations if known and planned mitigating measures are successfully employed.

Most mammal species should be little affected along the proposed route if planned mitigative measures are employed. Winter construction would avoid contact with the Porcupine caribou herd if stopped in advance of the spring migration and no barriers to movement were left, as is planned by the Applicant. Control of firearms and prohibition of hunting would remove a principal threat to game animals in the Arctic and Subarctic. Planned right-of-way alignments avoiding denning sites of wolves, foxes and grizzly bears along northern parts of the route will remove some of the principal threats to these species.

Adverse effects would be expected on such vulnerable species as wolverine, grizzly bear, and polar bear and to tundra populations of wolf in the Yukon and Northwest Territories. Although most potential adverse effects would be avoidable, noise disturbance by aircraft, harassment, and increased hunting pressure by hunters who benefited by increased accessibility of the area would be continuing threats to game animals and to the subsistence of Native peoples.

Use of the proposed route would adversely affect bird habitats on the right-of-way and in areas occupied by permanent facilities but the areas would be small relative to the total habitat resource.

Disturbances to migrating, nesting, feeding, molting and staging waterfowl and shorebirds and disruptions to the habitats used for these functions would be potential adverse effects at one time or another over essentially the full length of the proposed route. Especially critical habitat occurs along the Mackenzie River, in its delta, and along the shores, estuaries, lagoons and barrier beaches of the Yukon coast. Local summer construction of facilities, summer marine, river and air transportation, and noise of all kinds present throughout the operational period of pipeline, would be disruptive to waterfowl and shorebirds.

Economic Factors

The proposed project would in some degree have an adverse effect on the desire and/or ability of the Native local residents to follow their traditional hunting-trapping-fishing land-based economy. A trend away from the land-related pursuits toward a wage economy, however, has already been established in many parts of the proposed route region. Therefore, in general the proposed project could not be regarded as an initial cause, but it might be a potent factor in augmenting and accelerating this trend.

Some adverse effect, due to unemployment, might result in the postconstruction phase of the proposed pipeline project when the labor force required would be only a small fraction of that needed during the peak years of construction. Other secondary activities in gas and oil exploration and development in the Mackenzie region might materialize and provide continuing employment for those displaced from jobs following the projected peak construction period.

Sociological Factors

To some degree the various activities directly and indirectly associated with the proposed pipeline project would be likely to result in significant relocation and concentration changes in the population of the northern regions, as well as in a net total increase. Depending upon how these situations were handled, what the attitudes of the local residents would be at that time, and what one's opinion is of such a change, these changes might or might not have an adverse impact.

Land Use

Should the proposed project be adopted, the right-of-way (120 feet wide), the land occupied by borrow pits and quarries and by roads that served only the project, and the land occupied by compressor stations, communications sites, material marshalling areas, wharves, and the like, would be committed during the construction phase of the project. After construction had been completed much of the right-of-way and all temporary facilities, including borrow pits not needed for maintenance, would be available for nonpipeline-related uses.

Archeological and Historical Factors

Adverse effects on archeological resources along the proposed route would be inversely proportional to the extent and effectiveness of the archeological salvage program. Some unidentified sites would very likely be damaged or destroyed, but their number and value cannot be estimated. Because of the limited knowledge of archeological sites in the Arctic and Subarctic, the potential loss of sites is especially critical.

Recreation and Esthetic Factors

In the regions traversed by the proposed pipeline north of 60° N latitude, the main adverse effect on recreation resources would be in the form of landscape scarring from construction of the pipeline and related roads, borrow pits, airstrips, compressor stations, communication sites, wharves, etc. Other landscape scars would result if underlying permafrost were to be thawed, causing settlement and erosion.

The proposed project by itself would have adverse effects on some wilderness areas, notably the arctic coastal region. Of greater importance would be the major invasion of wilderness areas set off by the proposed project. By its roads and rights-of-way it would make the land more accessible to those who would come later. It would also stimulate related development in transportation, recreation and industry, as does any large project.

South of 60° N latitude, the proposed project would have only minor effect on recreation and esthetic resources because the route would essentially parallel an existing pipeline right-of-way for a large part of the distance in Alberta.

Approximately 1,050 miles of the entire route would closely parallel existing roads or pipelines; an additional 1,000 miles would extend through the Mackenzie Valley, a locus of settlement along the Mackenzie River transportation corridor in northwestern Canada and the site of a major transportation development, the partially completed Mackenzie Highway. The remaining 385 miles consists primarily of wilderness or very lightly developed areas.

3.1.2.1 Climate

Impact of the Proposed Pipeline System on Climate

The short-term effects of construction and operation of the proposed pipeline on climate would be minimal. In areas where temperatures of -22° F occur in conjunction with temperature inversion and low wind velocity, the addition of emissions from compressor stations and internal combustion engines in construction and maintenance vehicles would cause ice fog at times. This condition is local, is considered to be not deleterious to the environment, and would have no effect on regional climatic patterns. If airstrips were not sited at elevations higher than sources of particulate emissions, catabatic flow of ice fog would interfere with air traffic as long as low temperature and wind velocity and temperature inversion persisted, a time that probably would not exceed a few hours or, rarely, a few days.

Impact of Climate on Construction and Operation of the Pipeline System

Arctic and subarctic climates impose stringent environmental constraints on all human activities and are relatively unforgiving of mistakes. Penalties are severe for all failures to understand and work with these extreme environments. Both people and technologies introduced to the North from more temperate latitudes are prone to failure and to costly and time-consuming adjustments. Stresses on personnel, materials, equipment, and machines are extreme and the priorities must be high both for training of people for efficient and productive work and for engineering designs that fully take into consideration the special requirements of the environment.

Low temperatures of winter, compounded by the effect of often strong and persistent winds, produce wind-chill in excess of -100° F which is a threat to survival, a source of discomfort, and the cause of inefficiency or cessation of work. The unfavorable ambient temperature environment, combined with long winter darkness, is depressing to personnel and promotes inefficiency and adverse psychological effects. All tasks in the out-of-doors in the North are burdensome and highly energy-consuming and under worst conditions engender carelessness in performance.

The cold, darkness, blowing snow, and slippery surfaces make most tasks hazardous to workers, and maintenance of health, comfort and well-being is difficult. Work time lost through personnel or machinery failures would be intimately related to winter weather patterns during construction, and work schedules and seasonal completion dates would be subject to delays. An accelerated work pace to compensate for such delays would impose an added element of hazard. Work dates extended to compensate for inadvertent delays in areas of arctic winter construction could have serious environmental impacts, for example, in misuse of snow-ice roads after beginning of spring thaw.

Arctic winter construction north of 65° N latitude would make extensive use of snow, ice-capped snow, or ice roads and work pads on the right-of-way and as access to borrow pits, camps, wharves and stockpiles, and construction sites. Local availability of adequate quantities of snow could be a major problem everywhere in a particular winter and it might be necessary to haul snow for long distances. On the Arctic Slope of the Yukon precipitation is light at all times of the year, winter snowfall is scanty, and snow depth rarely exceeds 15 inches. Snow is subject to much redistribution by winds and the low foothills crossed by the proposed route are often swept essentially clear of snow.

Mining of snow from areas of drift accumulation would be damaging to shrub or tree types of vegetation and if mining were attempted before the ground was solidly frozen, the peat-moss mat would be compressed and excessive thaw would result the following warm season. In the absence of adequate snow there would be an increased demand for water for the construction of ice roads. Water is a scarce resource in winter in the North as lakes and streams may be frozen to depths of 6 feet or more. On the Arctic Slope lakes are shallow and may be frozen to the bottom and lack any available water. Deeper lakes with barely sufficient water to support overwintering fish populations could be critically affected by pumping of the residual water. Long-distance hauling of water from deeper lakes would entail an increased requirement for snow-ice access roads or cross-country travel that would have the same terrain impacts as mining of snow.

Climate would impose serious limitations upon transportation systems in northern Canada during mobilization and stockpiling prior to construction, during the winters of construction, and throughout the years of operation of the proposed pipeline. The lack of roads necessitates barge transportation on the Mackenzie River and along the Beaufort Sea coast for heavy equipment and massive materials and supplies. Barging is also the Applicant's preferred method of shipping and will be employed even if access highways are available. Heavy reliance on aircraft would be essential for movement of large volumes of air-transportable equipment, supplies, and personnel, and for surveillance, resupply, and emergency repair services throughout the life of the pipeline.

Low ground visibility impedes landing and take-off of aircraft, especially in the region of the arctic coast, and the total weather complex makes aircraft maintenance difficult, impedes search and rescue in case of accidents, and is a threat to survival of passengers and crew. Flying conditions are generally favorable in the far North from late February, when the sun reappears, until the summer warm season, when water is open in lakes and the ocean, and the incidence of foggy days increases. In the maritime climate of the Beaufort Sea coast summer weather is characterized by coolness, cloudiness, persistent winds, and fog. Along the coast, rapid changes in visibility due to onset of advection fog makes flying uncertain and causes long and unpredictable delays in meeting flying schedules. In the Mackenzie Delta, however, only about 3 percent of the days of the year are characterized by problems in flying and the percentage of unfavorable days decreases in the interior (i.e., about 2 percent at Norman Wells) (AAGPC, 1975).

Air operations could be hampered by ice fog at times at any of the airstrips located at compression stations, depending in part upon their relative siting. Ice fog forms whenever a source of water vapor is available and air temperature is -22° F or lower. Water vapor from compressor turbines would provide a constant potential of warm fog or ice fog at appropriate temperatures, especially under conditions of temperature inversion and absence of air movement.

The short-term impact of climate on marine shipping would operate through the same conditions of poor visibility that hamper air traffic and, more significantly, by the presence and seasonal behavior of sea ice. The Beaufort Sea coast is ice-locked for 9 or more months each year. The open water shipping season lasts for only 2 or 3 months in most years, rarely extends for longer periods into the autumn season, and in some years navigation is essentially impossible at any time with any measure of safety. By early July melting has normally freed the shorefast ice and under suitable wind patterns the ice pack will drift away and free the shipping lanes. The ice may be under pressure and be held in-shore for longer than normal periods or may drift away and unpredictably return to trap barges and ships.

The wind-driven, clockwise circulation of the Beaufort Sea gyre sweeps ice southwestward along the Arctic Archipelago and may keep ice jammed on the coast most of the summer. Access to the coast from Point Barrow eastward along Alaska and the Yukon, in any given year may be limited, always requires ice breaker support, and usually demands opportunism in ship movements. Shipping on the Mackenzie River, which would be utilized by the Applicant in large part, normally does not require ice breaker support but it is needed in some years to gain access to the ocean and work along the coast. Ice movements cannot be reliably forecast and reliance on stockpiling in a single shipping season prior to pipeline construction could have the impact of delaying construction 1 or more years. The Prudhoe Bay Supply Line would be affected most and delays would have serious effects on the delivery of needed Alaskan gas to the conterminous United States.

The extremely low winter temperatures in the North, especially in the continental climate of the subarctic interior of Canada, place a high premium on the properties of metals utilized in engineering structures and equipment. The structural integrity of the proposed pipeline, for example, is critical, not only for safe, efficient, economical delivery of gas, but for the protection of environmental values. There is no background of experience for the construction of a high-pressure, refrigerated pipeline at the ambient temperatures characteristic of northern Alaska and Canada, although there is much experience in northern Alberta with construction of pipelines lacking refrigeration. Analyses of brittleness, toughness, and stress characteristics of steel the Applicant has proposed for use in the Alaska segment of the pipeline system have raised questions as to the probable strength, integrity, and safety of the proposed pipeline. If these analyses apply also to the proposed Canadian pipeline, geologic hazards to the pipeline, as well as all impacts on the environment, such as fire, threats to human safety, and damage to terrain, vegetation and wildlife habitat during summer repair efforts, would occur at higher levels of incidence and degree.

In the area of conventional winter construction, from 65° N latitude to Caroline Junction, the impact of climate would be essentially the same as on land farther north, as described. Southward across Alberta the increasing road network would reduce the requirement for air support, and climatic hazards to flying would be of less significance than in the Territories.

From Caroline Junction to Monchy, Saskatchewan, and Kingsgate, British Columbia, construction would be accomplished in the summer season and there would probably be no significant impacts of climate on the proposed pipeline or ancillary facilities.

3.1.2.2 Topography

Slopes

In terms of impacts that construction of the proposed Arctic Gas Pipeline would have on the topography the slope of the ground is the primary element. In most places it is not the slope itself, but the combination of slope with various types of geologic materials and conditions that is responsible for a resultant impact (for example, a large landslide). For this reason the role of the slope of the ground in determining the potential for impact is analyzed in Section 3.1.2.3, Geology, where slope is one of the components of the SPG Index along with geological elements. In this section, however, the location and nature of slopes themselves are listed and analyzed for the various parts of the proposed route across Canada.

Generally, the steeper and longer (and consequently higher) the slope the greater will be the contributing effect of the slope element. Steepness categories used here are the same as those used in Section 2.1.2.2. Those slopes under 5 percent (3°), namely the nearly flat, very gentle, and gentle slopes, would cause negligible impact and are not further analyzed. The remaining categories, moderate, moderately steep, steep, and very steep, have an increasingly important role in determining potential impact, ranging from relatively small for moderate slopes to quite significant, regardless of the other elements present, for very steep slopes.

Arbitrary categories of length are established here for ease of analysis. The approximate median points of these categories are 0.1, 0.2, and 0.4 mile, with longer slopes categorized in terms of the nearest whole mile of length. These length categories include both single slopes and sequences of adjacent slopes of the same steepness category that alternate between upward and downward slopes. Slopes shorter than 200 feet are generally omitted because, except where they are relatively steep, they are too small to identify accurately on the Alignment Sheets. Consequently the representation is not equal for all combinations of length and steepness categories; however, short slopes probably are not as significant as longer ones in terms of impact except where they are steep, so that the lower cutoff points for counting length of slope have an approximately constant significance to impact even though they are not at the same lengths.

The measurements used here are based entirely on the profiles shown on the Alignment Sheets provided by the Applicant, and not on measurements on the ground. Thus there is room for error in the interpretation of slopes (presumably from air photos) and their representation on the Alignment Sheets and in the reading of the slope off the Alignment Sheets. While departures from the ground situation because of both of these processes exist, the degree of accuracy obtained is probably sufficient to give a general picture of the slope along the route suitable for the kind of generalized analysis presented in Section 3.1.2.3.

Tables 3.1.2.2-1 through 3.1.2.2-6 list segments of the six major parts of the route that fall into various combinations of steepness and length categories. Each segment, comprising a single slope or a group of slopes, is identified by the nearest milepost number. In Table 3.1.2.2-7, the heights of slopes higher than 100 feet are listed to the nearest 25 feet as measured from the Alignment Sheets. Three of the latter are along the Main Line, at the crossings of the Peace River, Athabasca River, and Windfall Creek. The remainder are on the Kingsgate Delivery Line, the highest being 3,000 feet.

Tables 3.1.2.2-8 through 3.1.2.2-13 summarize the preceding tables, and give the number of occurrences and total length of slopes in each of the combinations of steepness and length categories along each of the parts of the route. The highest number of segments of moderate slope fall in the 0.2-mile length category except on the Monchy Delivery Line where shorter lengths dominate. In all steeper categories of slope, lengths in the 0.1-mile category dominate, with substantially fewer slopes in the longer categories. Only on the Kingsgate Delivery Line is there a substantial number (7, totaling 8 miles) of slopes in the moderately steep and steep categories that are 1 mile or more in length. With one exception, very steep slopes occur only in the shortest length category, and most of these are less than 0.1 mile long.

Table 3.1.2.2-14 provides the number of segments, number of miles and percentage of the total length of each of the parts of the route that fall within each of the slope categories. With few exceptions, both number of slopes and length of such slopes decrease with increasing slope on all parts of the route. Expectedly, the Kingsgate Delivery Line has the highest percentage of length, about 26 percent, that exceeds 5 percent in slope. The Richards Island Supply Line and the Monchy Delivery Line have about 14 percent of their lengths with such slope, while the remaining parts have only about 8 percent in this category. For the entire route in Canada, slightly less than 12 percent of the route has slopes in excess of 5 percent, and only about 5 percent of the route exceeds a 10 percent slope. Thus, only a small part of the route is critically affected by steepness of slope, but in this small part impacts on both the environment and the pipeline could be severe.

Table 3.1.2.2-1 Location of slopes greater than 5 percent along the Prudhoe Bay Supply Line

Slopes are designed by milepost number and grouped according to length and steepness

Length Categories[1/]	Moderate Slopes (5-10%)	Moderately Steep Slopes (10-25%)	Steep Slopes (25-70%)	Very Steep Slopes (>70%)
0.1 mile	218 363 222 363 242 396 253 423 254 425 255 440 262 456 263 306 335	204 266 459 213 269 460 234 269 235 287 238 409 245 439 251 446 252 453 265 453 266 457	279 408 455 279 431 458 307 432 310 444 317 446 326 447 327 447 327 451 375 454 376 455	211 244 408
0.2 mile	206 329 360 440 214 331 367 457 244 336 420 468 299 337 422 304 344 427 310 345 428 320 354 429 321 355 433 322 358 437 326 359 439	209 441 211 227 244 246 255 285 331 353 365	205 307 323 331 336 339	
0.4 mile	208 370 249 296 338 352	362		
1 mile or more	228-229 333-334 442-443			

[1/] approximate average length

Table 3.1.2.2-2 Location of slopes greater than 5 percent along the Richards Island Supply Line and the Parsons Lake Lateral Line

Slopes are designed by milepost number and grouped according to length and steepness

Length Categories 1/	Moderate Slopes (5-10%)	Moderately Steep Slopes (10-25%)	Steep Slopes (25-70%)	Very Steep Slopes (>70%)
0.1 mile	11 36 118	19 85 23 85 34 86 55 90 65 112 72 129 79 (9) 82 (9) 82 (12) 84	24 72 28 79 50 80 51 98 51 100 57 105 60 110 61 112 66 (1) 67 (3)	29
0.2 mile	31 81 35 93 35 104 41 128 47 (2) 57 (4) 58 (7) 63 (8) 66 76	49 71 (3) (6) (10)	29	
0.4 mile	50 52 106 143 (0) (7)	44 56 142		
1 mile or more	12-14 18-19 39-40 46-47 58-60 70-71 73-75			

1/ approximate average length

Table 3.1.2.2-3 Location of slopes greater than 5 percent along the Main Line north of 60° N latitude

Slopes are designed by milepost number and grouped according to length and steepness

Length Categories[1/]	Moderate Slopes (5-10%)	Moderately Steep Slopes (10-25%)	Steep Slopes (25-70%)	Very Steep Slopes (>70%)
0.1 mile	158 510 604 699 821 167 530 606 714 167 532 606 736 168 567 609 737 357 569 617 747 365 570 656 806 366 578 684 807 393 592 692 808 401 593 694 818 438 596 695 820	132 164 369 434 582 605 133 166 371 435 592 643 136 211 387 456 593 684 141 212 387 508 593 692 141 213 389 509 595 144 330 391 528 596 146 331 392 562 600 156 337 398 562 604 163 347 402 569 605 164 365 408 570 605	130 402 562 606 217 402 562 643 332 403 565 683 357 423 576 684 357 436 592 701 389 439 604 702 391 447 605 392 465 605 398 480 606 401 533 606	285 422 422 542
0.2 mile	151 250 355 382 557 600 162 254 357 414 558 600 171 257 358 434 560 606 173 320 362 435 569 607 173 331 367 458 575 609 176 331 368 469 577 643 189 337 369 489 593 692 233 338 376 506 596 706 238 338 378 507 597 747 242 345 380 535 599 770 806 818	142 349 485 176 362 534 219 364 534 222 369 538 223 388 542 247 390 561 330 412 575 334 462 576 337 466 582 348 471	219 537 285 561 345 566 347 574 385 595 389 400 414 485 509	
0.4 mile	150 319 421 594 153 334 484 177 335 484 195 337 556 225 339 559 227 370 574 258 374 575 279 386 582 285 393 583 306 399 591	226 562 565 644	269 318 413 479 487 541 595	
1 mile or more	231-232 252-253 644-646	126-127 504-505 563-564		

[1/] approximate average length

Table 3.1.2.2-4 Location of slopes greater than 5 percent along the Main Line south of 60° N latitude

Slopes are designed by milepost number and grouped according to length and steepness

Length Categories[1/]	Moderate Slopes (5-10%)	Moderately Steep Slopes (10-25%)	Steep Slopes (25-70%)	Very Steep Slopes (>70%)
0.1 mile	851 854 1202 1235 1298 1306 1426	895 940 1017 1175 1213 1257 1370 903 942 1018 1177 1214 1257 1371 918 971 1029 1183 1217 1262 1375 924 972 1034 1191 1218 1262 1375 930 974 1047 1192 1224 1262 1376 991 1051 1198 1243 1298 1388 999 1071 1202 1243 1300 1000 1072 1205 1246 1307 1004 1091 1208 1248 1311 1007 1174 1209 1250 1351	869 971 1029 1192 1261 1411 924 972 1051 1193 1270 1416 930 974 1072 1194 1344 1427 957 976 1111 1198 1348 1427 990 1133 1199 1353 1428 991 1151 1205 1360 996 1162 1217 1374 998 1163 1218 1374 999 1187 1235 1383 1027 1191 1254 1390	996 1253 1425 997 1254 997 1315 998 1341 1003 1352 1003 1380 1003 1393 1043 1420 1043 1420 1147 1423
0.2 mile	951 1066 1250 1368 986 1111 1253 1373 991 1140 1267 1379 996 1141 1269 1384 1017 1166 1278 1393 1018 1168 1283 1423 1019 1194 1286 1424 1027 1236 1291 1425 1245 1342 1248 1359	910 1275 987 1277 1066 1289 1138 1373 1141 1423 1245 1426 1258 1260 1260 1267	987 1113 1140 1141 1250 1253 1264 1341 1350 1352	
0.4 mile	984 1383 987 1066 1080 1114 1154 1276 1287 1289 1356	1111 1113 1255 1374	1255	
1 mile or more	982-983 1347-1349 1059-1060 1353-1354 1164-1165 1362-1363 1246-1247 1370-1372 1251-1252 1375-1377 1257-1258 1391-1392 1259-1260 1428-1429 1261-1263 1271-1272 1344-1345			

[1/] approximate average length

Table 3.1.2.2-5 Location of slopes greater than 5 percent along the Monchy Delivery Line

Slopes are designed by milepost number and grouped according to length and steepness

Length Categories[1]	Moderate Slopes (5-10%)	Moderately Steep Slopes (10-25%)	Steep Slopes (25-70%)	Very Steep Slopes (>70%)
0.1 mile	7 41 91 122 182 212 227 7 61 100 123 197 218 311 17 64 101 124 197 218 322 21 64 101 124 198 223 349 21 73 103 124 199 223 22 75 108 125 206 224 23 75 114 126 209 226 25 76 114 131 210 226 27 76 114 181 211 227 41 81 115 181 211 227	0 71 88 111 151 202 301 361 3 72 91 115 152 204 303 370 4 73 92 118 152 204 311 382 15 75 93 118 152 206 329 390 15 75 94 125 156 214 336 16 78 103 129 177 217 337 43 80 106 130 177 219 343 44 80 106 131 179 222 350 64 82 109 141 199 227 353 66 82 111 143 201 246 359	0 56 94 116 199 308 386 1 61 95 116 199 313 2 72 98 117 200 316 10 80 98 117 201 318 14 80 100 160 203 351 37 81 102 161 205 352 39 82 103 166 210 355 39 88 113 166 218 356 50 91 113 167 306 369 56 92 113 167 307 385	2 171 8 198 73 210 88 228 95 228 96 361 97 98 166 167
0.2 mile	0 65 117 195 312 1 72 119 205 352 2 78 120 208 369 6 80 121 209 6 84 154 238 10 90 168 246 14 99 180 287 29 102 180 291 35 106 180 301 56 112 192 309	37 202 61 209 86 210 89 211 99 211 100 213 113 310 160 313 198 351 202	99 109 151 161 167 171 214 312 313 354	151
0.4 mile	16 313 37 316 56 354 81 359 93 110 193 204 213 229			
1 mile or more	97-98 350-351 104-105 165-166 176-179 196-197 198-200 201-202 203-204 215-216 217-218	228-229		

---

[1] approximate average length

Table 3.1.2.2-6 Location of slopes greater than 5 percent along the Kingsgate Delivery Line

Slopes are designed by milepost number and grouped according to length and steepness

Length Categories[1/]	Moderate Slopes (5-10%)	Moderately Steep Slopes (10-25%)	Steep Slopes (25-70%)	Very Steep Slopes (>70%)
0.1 mile	6 27 63 80 97 252 263 265 273 281	0 16 79 236 2 17 87 239 6 22 97 271 6 27 98 274 8 27 142 274 8 28 159 278 9 44 186 278 9 48 225 12 56 232 13 62 234	1 38 66 97 128 178 236 268 1 40 70 98 138 201 238 269 1 42 75 104 141 209 249 277 6 43 76 107 149 212 249 278 7 55 81 107 158 213 250 9 58 81 109 163 215 256 10 62 84 112 164 216 258 12 63 85 116 167 224 264 32 64 89 122 173 232 265 37 65 92 128 176 235 266	6 117 173 243 7 118 174 250 22 120 177 256 75 123 205 264 84 126 209 273 94 143 211 274 98 146 216 106 149 218 108 158 218 115 171 231
0.2 mile	0 66 129 164 214 22 67 131 165 252 28 76 132 173 257 31 78 134 177 261 35 86 136 183 264 41 91 147 190 276 43 121 150 191 280 51 122 155 196 280 52 123 156 204 53 126 156 205	0 149 201 250 8 150 203 262 36 155 204 272 55 166 204 74 177 208 89 179 208 135 180 224 136 195 225 139 195 232 147 200 238	54 170 250 54 178 276 73 180 100 195 101 202 149 202 150 204 155 205 166 224 166 243	
0.4 mile	29 178 30 193 38 200 57 201 89 235 91 242 107 246 128 275 145 171	7 41 165 172 176 180 187 202 205	137 137 179 203 218 248	
1 mile or more	140-141 141-142 148-149 154-155 168-169 174-175 186-187 197-198 223-224 226-232	157-158 188-189 249-250 251-252 254-255	206-208 253-254	

[1/] approximate average length

Table 3.1.2.2-7 Location of those slopes greater than 5 percent that are higher than 100 feet

Milepost	Slope Category1/	Height (ft)2/	Named geographic feature associated with slope
Prudhoe Bay Supply Line			
244	R	125	
307	SR	200	
307	S	125	Blow River
323	S	175	
323	S	175	
331	S	175	
331	SR	275	
333	M	150	
336	MS	250	
338	MS	350	Fish River
Richards Island Supply Line			
12-14	M	125	
39-40	M	200	
46-47	M	175	
56	R	150	
57	SM	150	
58-60	M	200	
58-60	M	200	
70-71	M	125	
142	RM	200	
Main Line North of 60° N Latitude			
126-127	R	250	
173	MR	125	
177	S	250	Thunder River
177	S	250	Thunder River
219	SR	300	
226	RM	250	

1/ M: moderate (5-10%); R: moderately steep (10-25%); S: steep (25-70%); V: very steep (greater than 70%). Where more than one letter appears, dominant category appears first.

2/ given as nearest 25 feet

Table 3.1.2.2-7 Continued

	Main Line North of 60° N Latitude (continued)		
231-232	M	150	
252-253	M	150	
285	SV	150	
318	S	150	
318	S	150	
319	M	150	
331	MS	225	
337	RM	125	
370	MR	125	
386	MS	150	
393	SM	125	
393	SM	125	
413	S	325	
414	MS	150	
421	MV	150	
422	V	125	
479	S	250	Saline River
479	SR	150	Saline River
485	SR	125	
487	S	175	
487	S	175	
504-505	R	225	Blackwater River
504-505	R	225	Blackwater River
537	S	125	
538	R	125	
541	S	175	
542	SR	175	
583	M	150	River Between Two Mountains
591-592	MRS	300	
593	RM	250	
594	M	125	
595	SR	250	
597	M	125	
604-605	MRS	250	
605	RS	150	
605-607	MS	350	
642-646	MRS	1450	Trail River
684	SRM	250	Mackenzie River

Table 3.1.2.2-7 Continued

	Main Line South of 60° N Latitude		
982-983	M	250	Naylor Hills
987	SRM	200	
988	M	200	
991	MRS	175	
1059-1060	M	200	
1066	R	125	
1066	RM	250	
1080	M	200	
1111	RMS	400	Peace River
1114	RMS	700	Peace River
1140	SM	400	Smoky River
1141	MSR	500	Smoky River
1246-1247	M	400	
1251-1252	SM	650	Athabasca River
1253	VR	300	
1255	RS	400	
1255	S	150	
1257-1258	MR	250	
1259-1260	RM	450	
1261	RSM	500	Windfall Creek
1263	MS	600	Windfall Creek
1267	MR	175	
1271-1272	M	275	
1289	MS	300	McLeod River plain
1341	SR	150	Pembina River
1347	M	250	
1350	S	200	N. Saskatchewan River
1352	SV	300	N. Saskatchewan River
1353	MS	225	N. Saskatchewan River
1370	MR	150	
1371	M	125	
1373	MR	150	
1374	RS	150	
1374	RS	225	
1375	MS	150	
1376	RM	275	
1376	MR	175	
1391	M	200	

Table 3.1.2.2-7 Continued

Monchy Delivery Line

8	V	175	Red Deer River
10	MS	175	Red Deer River
37	MRS	200	
86	R	125	
93	M	150	
97	M	150	
97	M	200	
99	SM	150	
100	RM	125	
151	V	200	Matzhiwin Creek
151	VSR	275	Matzhiwin Creek
165	M	150	
167	VR	150	
167	S	150	
171	S	125	Wolf Coulee
172	V	125	Wolf Coulee
176	MR	150	
213	M	150	
228	VR	325	S. Saskatchewan River
229	RM	475	S. Saskatchewan River
310	RM	300	
312	SM	275	Bone Creek
313	SRM	400	Bone Creek
351	RM	250	Bate Creek
351	R	200	Bate Creek
354	MS	150	

Kingsgate Delivery Line

0	RM	325	James River
1	RS	150	James River
6	SRV	125	
7	RS	125	
8	V	150	
9	SR	150	
22	VR	175	
29	MR	300	Little Red Deer River
53	SM	225	Bow River
55	RS	250	Bow River
75	VSR	250	
79	MR	150	Fish Creek
89	RS	300	
89	M	150	
128	M	125	

Table 3.1.2.2-7 Continued

	Kingsgate Delivery Line (continued)		
137	SRM	1300	Rocky Mts. Forest Preserve
142	MR	300	
147	RM	200	Livingstone River
148	M	300	
149	SR	400	
150	RS	250	
150	RSM	600	
154	M	500	
155	S	325	
156	RM	150	
157	RV	500	
165	R	400	
166	SR	500	
168	M	300	
170	S	300	
171	MV	300	
172	R	400	
174	MV	200	
176	RS	500	
177	R	200	
178	SV	125	
178	M	125	
178	RS	500	
179	S	200	
180	RS	1000	
186	M	300	
187	R	200	
188	R	125	
191	M	125	
193	M	200	
195	RS	400	
196	MR	200	
197	M	300	
200	MR	300	
201	RSM	400	
202	SM	350	
202	SR	625	
203	SR	825	
204	SR	600	
205	SRM	900	
206	V	200	
207	S	3000	
209	VRS	200	
211	V	200	
216	S	200	

Table 3.1.2.2-7 Continued

	Kingsgate Delivery Line (continued)		
216	V	150	
218	SV	900	
218	V	400	
223	MR	375	
225	R	200	
227	M	200	Big Sand Creek
229	M	150	Big Sand Creek
230	M	300	Kootenay River
232	VRM	400	Kootenay River
232	SR	200	
238	R	150	
239	SR	200	
243	SM	150	
246	M	200	
248-250	SRV	2150	
251	VSR	400	
251-255	SRM	2850	
262	SM	200	
264	VSM	250	
275	MSR	425	
276	S	400	
280	M	175	

Table 3.1.2.2-8 Summary of steepness and length of slopes along the Prudhoe Bay Supply Line

Categories of steepness Categories of length	Moderate Slopes (5-10%)		Moderately Steep Slopes (10-25%)		Steep Slopes (25-70%)		Very Steep Slopes (>70%)		All slopes greater than 5%	
	Number	Miles	Number	Miles	Number	Miles	Number	Miles	Number	Miles
0.1 mile	17	1.7	22	2.2	22	2.2	3	.3	64	6.4
0.2 mile	33	6.6	11	2.2	6	1.2	–	–	50	10.0
0.4 mile	6	2.4	1	.4	–	–	–	–	7	2.8
1 mile or more	3	3.0	–	–	–	–	–	–	3	3.0
Total	59	13.7	34	4.8	28	3.4	3	.3	124	22.2

Table 3.1.2.2-9 Summary of steepness and length of slopes along the Richards Island Supply Line and the Parsons Lake Lateral Line

Steepness / Length	Moderate Slopes (5-10%)		Moderately Steep Slopes (10-25%)		Steep Slopes (25-70%)		Very Steep Slopes (>70%)		All slopes greater than 5%	
	Number	Miles	Number	Miles	Number	Miles	Number	Miles	Number	Miles
0.1 mile	3	.3	19	1.9	20	2.0	1	.1	43	4.3
0.2 mile	18	3.6	5	1.0	1	.2	–	–	24	4.8
0.4 mile	6	2.4	3	1.2	–	–	–	–	9	3.6
1 mile or more	7	10.0	–	–	–	–	–	–	7	10.0
Total	34	16.3	27	4.1	21	2.2	1	.1	83	22.7

Table 3.1.2.2-10 Summary of steepness and length of slopes along the Main Line north of 60° N latitude

Steepness / Length	Moderate Slopes (5-10%)		Moderately Steep Slopes (10-25%)		Steep Slopes (25-70%)		Very Steep Slopes (>70%)		All slopes greater than 5%	
	Number	Miles	Number	Miles	Number	Miles	Number	Miles	Number	Miles
0.1 mile	41	4.1	54	5.4	36	3.6	4	.4	135	13.5
0.2 mile	62	12.4	29	5.8	15	3.0	-	-	106	21.2
0.4 mile	31	12.4	4	1.6	6	2.4	-	-	41	16.4
1 mile or more	3	4.0	3	3.0	-	-	-	-	6	7.0
Total	137	32.9	90	15.8	57	9.0	4	.4	288	58.1

Table 3.1.2.2-11 Summary of steepness and length of slopes along the Main Line south of 60° N latitude

Steepness / Length	Moderate Slopes (5-10%)		Moderately Steep Slopes (10-25%)		Steep Slopes (25-70%)		Very Steep Slopes (>70%)		All slopes greater than 5%	
	Number	Miles	Number	Miles	Number	Miles	Number	Miles	Number	Miles
0.1 mile	7	0.7	62	6.2	49	4.9	21	2.1	139	13.9
0.2 mile	36	7.2	16	3.2	10	2.0	-	-	62	12.4
0.4 mile	11	4.4	4	1.6	1	0.4	-	-	16	6.4
1 mile or more	17	20.0	-	-	-	-	-	-	17	20.0
Total	71	32.3	82	11.0	60	7.3	21	2.1	234	52.7

Table 3.1.2.2-12 Summary of steepness and length of slopes along the Monchy Delivery Line

Steepness / Length	Moderate Slopes (5-10%)		Moderately Steep Slopes (10-25%)		Steep Slopes (25-70%)		Very Steep Slopes (>70%)		All slopes greater than 5%	
	Number	Miles	Number	Miles	Number	Miles	Number	Miles	Number	Miles
0.1 mile	64	6.4	74	7.4	61	6.1	16	1.6	215	21.5
0.2 mile	45	9.0	19	3.8	10	2.0	1	.2	75	15.0
0.4 mile	14	5.6	-	-	-	-	-	-	14	5.6
1 mile or more	11	14.0	1	1.0	-	-	-	-	12	15.0
Total	134	35.0	94	12.2	71	8.1	17	1.8	316	57.1

Table 3.1.2.2-13 Summary of steepness and length of slopes along the Kingsgate Delivery Line

Steepness / Length	Moderate Slopes (5-10%)		Moderately Steep Slopes (10-25%)		Steep Slopes (25-70%)		Very Steep Slopes (>70%)		All slopes greater than 5%	
	Number	Miles	Number	Miles	Number	Miles	Number	Miles	Number	Miles
0.1 mile	10	1.0	37	3.7	75	7.5	37	3.7	159	15.9
0.2 mile	48	9.6	33	6.6	22	4.4	-	-	103	20.6
0.4 mile	18	7.2	9	3.6	6	2.4	-	-	33	13.2
1 mile or more	10	15.0	5	5.0	2	3.0	-	-	17	23.0
Total	86	32.8	84	18.9	105	17.3	37	3.7	312	72.7

Table 3.1.2.2-14 Summary of slopes greater than 5 percent along all parts of the proposed route

Steepness	Moderate (5-10%)			Moderately Steep (10-25%)			Steep (25-70%)			Very Steep (>70%)			Total (>5%)		
Route	Number	Miles	%[a]	Number	Miles	%[a]	Number	Miles	%[a]	Number	Miles	%[a]	Number	Miles	%[a]
Prudhoe Bay Supply Line	59	13.7	4.6	34	4.8	1.6	28	3.4	1.1	3	0.3	0.1	124	22.2	7.4
Richards Island Supply Line	34	16.3	10.3	27	4.1	2.6	21	2.2	1.4	1	0.1	0.1	83	22.7	14.4
Main line North of 60°N Lat.	137	32.9	4.7	87	15.8	2.3	57	9.0	1.3	4	0.4	0.1	285	58.1	8.4
Main line South of 60°N Lat.	71	32.3	5.3	82	11.0	1.8	60	7.3	1.2	21	2.1	0.3	234	52.7	8.6
Monchy Delivery Line	134	35.0	8.9	94	12.2	3.1	71	8.1	2.1	17	1.8	0.5	316	57.1	14.5
Kingsgate Delivery Line	86	32.8	11.7	84	18.9	6.7	105	17.3	6.2	37	3.7	1.3	312	72.7	25.9
Total	521	163.0	6.7	408	66.8	2.7	342	47.3	1.9	83	8.4	0.4	1354	285.5	11.7

[a] figures show percent of route having indicated slope

Borrow Pits

The excavation of borrow pits would have a presumably permanent impact on the topography by the creation of a closed depression in ground with relatively flat surface, by the retreat of a substantially sloping surface, or by the removal of part or even all of a hill, terrace, or other topographically high area. In all cases there would be a net lowering of the surface of the ground.

To assess the magnitude of this impact, the list of borrow pits proposed by the Applicant (CAGPL, 1974d, App. A, p. 10-21) was analyzed to determine the area and depth of such topographic alteration. The results of this analysis appear on Tables 3.1.2.2-15 through 3.1.2.2-18. It was assumed that only one pit would be used where more than one was listed for a particular purpose, the additional pits being considered as alternatives; this includes 16 more than those so designated by the Applicant. For this analysis it makes no difference which of several alternative sites might ultimately be selected, or indeed whether more than one were used, as long as the volume of material extracted and average depth of excavation remained about the same. In order to determine the area that would be topographically impacted by the excavation of a pit, the volume of material required at each site was divided by the depth to which excavation would be made; both of these figures were furnished by the Applicant. This area has also been expressed in terms of possible dimensions in round numbers, assuming that a pit would be approximately square, to provide another measure of the magnitude of area involved. Naturally shapes of pit other than square are likely to be used, and it is not intended that the dimensions listed would necessarily be those actually used for any particular pit.

The indicated area of impact calculated in this way is probably a minimum figure, because to excavate such an area, a larger area would have to be disturbed in order to provide pit walls that were appropriately sloped rather than being vertical. In addition, if some of the material in a pit were not suited for the intended use, a larger area might have to be excavated in order to obtain the required volume of useful material. The unneeded material would be left in the pit, so that the net result might be a shallower topographic change over a larger area than calculated. The depth of the final remaining pit in many cases would be less than the given depth of excavation for other reasons. The pit might be partly filled with unneeded material excavated from the pipeline trench or with other debris resulting from construction procedures. In any case, the sloping pit wall would give rise to shallower depths at the edges of the pit.

The Applicant did not determine volumes of borrow material that would be needed for right-of-way purposes along the Prudhoe Bay Supply Line. For this analysis, an assumption of a total need of 2,000,000 cubic yards was used, based on needs for the Richards Island Supply Line and for that part of the Prudhoe Bay Supply Line in Alaska, for which figures were available. The total need for borrow material was divided evenly among the eight pits selected by the Applicant. This procedure should provide a total area of impact resulting from the extraction of borrow material for right-of-way purposes that is of the right order of magnitude, but individual pits for which the area was determined in this manner might actually be excavated over substantially larger or smaller areas.

No gravel pit needs are given for the Main Line south of about Milepost 941, or for the Monchy and Kingsgate Delivery Lines. The Applicant intends that borrow material for these lines be taken from existing pits. Such pits would have to be enlarged in area and (or) deepened, but such activity is probably rightly regarded as constituting an impact substantially below that

Table 3.1.2.2-15 Borrow pits along the Prudhoe Bay Supply Line

Milepost	Applicant's Designation	Required Volume[1/] (10^3 yd^3)	Estimated Recovery[1/] Depth (ft)	Approximate area of pit[2/] (10^3 ft^2)	Possible Dimensions of pit (ft)[2/]
196	GM107	2.8	10	8	90x90
198.5	124	250[3/]	10	680	800x850
223.6	125	1055	10	285	1690x1690
235	127	250[3/]	10	680	800x850
244	GM125	2	20	3	50x60
255.7	131	250[3/]	10	680	800x850
270	133	615	10	1660	1300x1300
308	137	250[3/]	10	680	800x850
316	138	615	10	1660	1300x1300
338	140	250[3/]	10	680	800x850
345	GM127	2	20	3	50x60
361	141	518	20	700	830x840
361	GM37	721	20	970	990x980
375	142	250[3/]	10	680	800x850
375	142A	250[3/]	10	680	800x850
377	GM128	2	5	11	100x110
385	143	242	20	330	570x570
407.5	147	1700	10	4590	2140x2150
432	237	290	20	390	600x650
457	244	280	20	380	600x630
458.5	GM42	365	20	500	700x710
475	249	250[3/]	10	680	800x850
477	GM129	2	10	5	70x70
486	252	1435	20	1940	1400x1400

1/ data from Applicant (Table 1, Appendix A, CAGPL, 1974, Responses to Pipeline Application Assessment Group Requests for Supplementary Information, p. 10-21).

2/ data calculated from Applicant's data; numbers are rounded to tens of thousands of square feet and tens of linear feet.

3/ not provided by Applicant; crude estimation from other Applicant data.

Table 3.1.2.2-16 Borrow pits along the Richards Island Supply Line

Milepost	Applicant's Designation	Required Volume[1] $(10^3\ yd^3)$	Estimated Recovery[1] Depth (ft)	Approximate area of pit[2] $(10^3\ ft^2)$	Possible Dimensions of pit (ft)[2]
2	GM135	24	10	65	250x250
18.5	3	118.6	5	640	800x800
23	GM134	291	5	160	400x400
26	10	118.6	20	160	400x400
39	GM137	364	30	330	570x570
39	GM132	565	10	1530	1200x1275
42	GM136	2	15	4	60x65
56.5	GM4	208.2	20	280	530x530
65	GM138	320	15	580	760x760
65.5	GM5	151	20	200	400x500
91	GM39	320	10	860	900x950
97	DPW	320	20	430	650x660
120	GM78	35.4	5	1910	1400x1400
129	GM140	2	10	5	70
130.3	256	91	10	250	500x500
142	GM96	91	10	250	500x500
0[3]	GM133	24	10	65	250x250

[1] data from Applicant (Table 1, Appendix A, CAGPL, 1974, Responses to Pipeline Application Assessment Group Requests for Supplementary Information, p. 10-21).

[2] data calculated from Applicant's data; numbers are rounded to tens of thousands of square feet and tens of linear feet.

[3] Parsons Lake Lateral Zone

Table 3.1.2.2-17 Borrow pits along the Main Line north of 60° N latitude

Milepost	Applicant's Designation	Required Volume1/ (10^3 yd^3)	Estimated Recovery1/ Depth (ft)	Approximate area of pit2/ (10^3 ft^2)	Possible Dimensions of pit (ft)2/
143	GM8a	1435	10	3880	2000x1940
143	GM116	2	20	3	60x50
177	GM10	1880	5	1015	3000x3400
199	GM117	2	10	5	70x70
203	303	119.1	10	320	500x640
211.6	306	106.5	10	290	500x580
218	308	640	15	1150	1200x1000
218	GM131	2	10	5	70x70
230.5	319	69.3	10	190	400x475
250.5	321	111	10	300	500x600
259	GM14	480	20	650	800x800
275.5	328	119.2	10	320	600x530
287.6	FGH2	244	20	330	600x550
293.2	FGH7	47	5	250	500x500
304.5	P315	47	10	130	400x325
312	P319	370	20	500	700x715
342	374	84.4	10	230	500x460
348	374a	84.4	20	110	300x360
356.9	P289	630	10	1700	1300x1300
357	GM118	2	10	5	70x70
367	413	187.7	20	250	500x500
373	NW15	175	10	470	690x680
388	P279	57.7	10	160	400x400
400.4	P266	330	5	1780	1300x1370
408.3	P262	76.5	10	210	500x420
446	150BH	450	20	610	780x780
446	P226	2	20	3	60x50
458	P242	49.8	10	130	400x325
465.5	P227	49.8	15	90	300x300
478.5	P213	96	15	170	410x415

1/ data from Applicant (Table 1, Appendix A, CAGPL, 1974, Responses to Pipeline Application Assessment Group Requests for Supplementary Information, p. 10-21).

2/ data calculated from Applicant's data; numbers are rounded to tens of thousands of square feet and tens of linear feet.

Table 3.1.2.2-17 (Cont.). Borrow pits along the Main Line north of 60° N Latitude

Milepost	Applicant's designation	Required volume[1/] (10^3 yd^3)	Estimated recovery depth (ft)	Approximate area of pit[2/] (10^3 ft^2)	Possible dimensions of pit (ft)[2/]
491	GM119	2	20	3	60x50
491	P197	615	20	830	910x910
507.5	P191	75.8	20	100	315x315
517	P183	60	15	140	300x360
538	P170	520	20	700	830x840
551	P159	115.5	10	310	500x620
565.3	W5	164.4	15	300	500x600
573.2	P152	118.6	10	320	580x550
579.5	P146	420	10	110	300x360
580	GM120	2	20	3	60x50
601	GM172	2	20	2.7	45x60
617	GM161	757	30	682	800x850
622	GM180	305	20	412	700x600
622	GM181	305	20	412	700x600
622	P118	305	20	412	700x600
663	P101	193	10	521	700x750
675	FS13	797	30	717	850x850
689	GM178	78	10	211	145x145
723	GM167	374	20	505	700x720
749	GM168	305	20	412	700x600
756	GM179	305	20	412	700x600
779	GM174	2	20	2.7	45x60
807	GM33	1,920	30	1,728	1320x1320
838	GM144	2	20	2.7	45x60
855	GM79	240	20	324	570x570
855	GM80	240	20	324	570x570
878	GM130	2	20	2.7	45x60
901	GM82	120	10	324	570x570

Table 3.1.2.2-18 Summary of borrow pit data

	Number of pits	Total volume (10^3 yd^3)	Total area	
			(10^3 ft^2)	(acres)
Prudhoe Bay Supply Line	24	9,846.8	18,875	433
Richards Island Supply Line	17	3,364.4	7,719	177
Main Line north of 60° N Latitude	53	14,436.4	25,775	592
Total	94	27,647.6	52,349	1,202

caused by the creation of new pits in undeveloped areas. In terms of topographic change, any new pits required for this part of the route, and it probably can be expected that some new pits will actually be required, would constitute an impact similar to that of new excavation farther north.

Tables 3.1.2.2-15 through 3.1.2.2-17 list by Milepost and Applicant designation the volume of material required, the expected depth of excavation, and the calculated area to be topographically altered as a result of the excavation for the two supply lines and the Main Line as far south as Milepost 941. Table 3.1.2.2-18 summarizes the total volumes required and areas disturbed.

The surface of the ground along the alignment of the pipeline would be modified along most of the route. The natural slope of the landscape would be changed, because directly over the pipe a nearly continuous low linear mound of geologic materials would be added along the centerline. The width of the mounded material would be about 5 feet. In addition to the impact of the nearly continuous mound, steeper slopes would have some scattered low mounds as much as several feet in maximum dimension. These mounds would be designed to control rapid flow of sheet wash during heavy rains and rapid snowmelt.

Although mounding of geologic materials would be the dominant change to the natural slope, several other activities related to construction would make topographic changes on the order of a few to several feet in height; these changes generally would not be of sufficient magnitude to show on a detailed (1:50,000-scale) topographic map. These newly formed irregularities could pond water or become deepened by erosion during heavy rains or rapid snowmelt. Along most of the route, irregularities of the ground surface formed during construction would be progressively less obtrusive with the passing of time because of settling of materials, growth of vegetation, and modification of short slopes by sheet wash.

3.1.2.3 Geology

Impact of the Pipeline and Related Structures

The impacts considered here are interactions between the proposed project and the geologic environment. In many cases the proposed pipeline would affect the geologic environment, but in other cases, the geology would affect the pipeline. For example, it is obvious that the pipeline would not affect the seismicity of the area; however, an earthquake-induced landslide could rupture the pipeline. In turn, the terrain disturbances caused during repair of the pipeline could have a significant impact on the geologic environment. It is particularly important to note in this regard that while construction of the pipeline could be undertaken during winter when optimal conditions for preserving the environment prevail, any rupture of the line would be more likely to occur during the season of thawing, and repair work undertaken at that time could have greater adverse impact on the environment than initial construction would have.

Because of the lack of precedent for a project of this type and magnitude in the Arctic, judgments about impacts are based on extrapolation from past experience, test data, and current understanding of the factors that can have a significant effect on the geologic environment. Moreover, the proposed project differs from other gas pipeline projects in that the pipeline would be constructed across an extensive permafrost region and the gas would be at temperatures below 32° F within most of this region and would be at pressures greater than 1,600 psi. The low gas transmission temperatures may have the effect of reducing the strength of the steel of which the pipe is made; should this be the case, the pipe would rupture more readily than it would otherwise when subjected to the external stresses resulting from the geological impacts discussed in this Section. These impacts would be heightened in intensity and quantity by use of pipe steel deficient in strength.

The kinds of geologic impacts that might occur along those parts of the route respectively north and south of the 60° N. latitude are discussed separately. Although many of the potential geologic impacts could occur at places along the entire route, there are changes that take place at about 60° N. latitude such as the occurrence of permafrost which is widespread to the north, but only scattered to the south. Following the descriptions of specific kinds of problems that have the potential of giving rise to impacts on the environment or on the pipeline, another section of this Statement presents a method of rating the entire route in general terms of the likelihood of occurrence of such potential impacts.

Disturbances Caused by Construction and Operation of Pipeline North of 60° N. Latitude

The basic procedures that would be used to construct the proposed pipeline system would be: 1) clear a right-of-way for the line, excavate a trench, lay a pipe, backfill the trench and dispose of excess material; 2) excavate natural materials required in the construction of roads, airstrips, helipads, communication sites, foundation pads for compressor and measurement stations, and bedding, padding, and select backfill for the pipeline trench; 3) clear areas and prepare them for compressor stations, block valves, and other facilities.

The impacts on the geologic resources caused by the construction, operation, maintenance, and abandonment of the proposed pipeline system would generally be limited to the immediate vicinity of pipeline and related facilities.

Extraction of Natural Construction Materials and Resulting Terrain Scars

Approximately 30 million cubic yards of construction material from borrow pits and quarries would be required for construction of the proposed pipeline system (CAGPL, 1974b, 14.d N, 2, p. 8). The impact caused by the excavation of borrow pits and rock quarries would mostly be limited to terrain scars, drainage disruption, and slope instabilities.

Undercutting natural slopes and oversteepening pit walls could result in local slumping. Shaping the pit and side slopes would be necessary to control accelerated erosion and ponding and to maintain slope stability. Excavation of borrow pits in permafrost areas could result in the thawing of permafrost, causing thaw subsidence and soil instability in ice-rich materials.

Some changes in the environment would be caused by the transportation and redistribution of borrow materials, but probably the most important impact of using the natural construction materials along the proposed pipeline route would be the expenditure of an essentially irreplaceable natural resource. Some of the borrow areas would have to remain open during the lifetime of the pipeline because of an intermittent requirement for material for maintenance purposes.

Drainage Disruption

Surface Drainage--The proposed pipeline alignment crosses numerous streams (Section 3.1.2.5). Because of the special engineering-geologic problems posed in these situations, each stream crossing and flood-plain area would require individual study prior to final design in order to select the special design measures necessary to minimize adverse environmental effects. The most important engineering-geologic considerations for crossings of flood plains and streams are determining: the maximum depth of scour of streams; maximum limits of the "Standard Project Flood"; potential for bank erosion and for erosion caused by channel changes; and the consequences of aufeis (a form of river ice) forming, where it normally does not, because of the cold buried pipe.

Once the pipeline system is completed, surface drainage would be affected by the berms, cuts, and other structures associated with the pipeline. Effects caused by disruption of surface drainage could not be completely eliminated, but, in most cases, could be so controlled that no widespread disturbance of surficial materials would occur.

Subsurface Drainage--Very little data are available on ground water occurrences and movement in the area of the proposed pipeline. Permafrost near the land surface generally limits movement of ground water to the active layer; beneath the permafrost, ground water movements should not be significantly affected by the construction or operation of the pipeline.

In areas away from rivers, the operation of the proposed chilled gas pipeline would reduce the thickness of the active layer above the axis of the pipeline. This raised permafrost table could act as a barrier to subsurface ground-water flow across the pipeline and could either direct the flow parallel to the pipeline or cause the water to surface.

The presence of a chilled gas pipeline in the bed of a river that has ground-water movement throughout the winter could form a frozen core that could effectively dam the stream, forcing the water to the surface, creating river icings where none had existed before. Icings would change the regime of the river, and consequently, could cause bank erosion and scouring at places where the pipeline would not be designed to accommodate these effects.

The full consequences of the impacts of a buried chilled gas pipeline on the movement of shallow ground-water are extremely difficult to predict; more information on these potential problems is needed to enable a detailed evaluation of environmental impacts.

Instability of Slopes

Slope instability is an extremely important engineering problem because if downslope movement of materials is deep enough to incorporate a pipeline, rupture of the pipe could result. Shallow downslope movement, such as solifluction, probably would not directly affect a pipeline, but it could result in redirected surface drainage, accelerated erosion, and thawing of permafrost, and consequently, could indirectly affect the integrity of a pipeline. Any massive downslope movement would cause a permanent change to the topography, and have an impact of varying duration on other aspects of the environment.

Thawing of permafrost because of construction and maintenance disturbances could result in slope failure, especially in slopes underlain by fine-grained ice-rich soils. Disturbance of the vegetation mat on slopes underlain by ice-rich permafrost should be minimized in order to prevent or restrict the thawing of the permafrost.

Accelerated Erosion

Accelerated erosion would be especially difficult to control along certain segments (see SPG charts, Figures 3.1.2.3-1 through 4) of the proposed pipeline route because fine-grained ice-rich permafrost soils are extremely sensitive to disturbance by man. During both the construction and maintenance phases, damage to the tundra by construction equipment could occur. In this event, the underlying permafrost would thaw more deeply in summer. Thawing of ice-rich permafrost would create new ponds and small streams, and cause soil flowage and erosion. Some of these effects would be irreversible.

Thawing of Permafrost and Effects of a Cold Buried Pipeline

One of the most critical factors to be considered is the thawing of perennially frozen ground. Thawing the permafrost and a variety of related effects such as the behavior of frozen soil when thawed are highly relevant to most of the other geologic factors covered in this statement.

Permafrost with little or no ice generally does not cause serious engineering or environmental problems, but permafrost that is ice-rich can cause extremely serious problems if allowed to thaw. Ice-rich fine-grained permafrost soils, when thawed, undergo a change in volume and a loss of strength. Any resulting differential settlement and instability could pose major problems.

In addition to the difficulties that normally confront major construction projects in permafrost areas, a buried chilled pipeline would pose special problems. 1) Heaving caused by the freezing of unfrozen water commonly present in fine-grained permafrost soils. Even though the ground temperature is below freezing, significant quantities of unfrozen water can be present in fine-grained soils. If the ground temperature were lowered by the chilled gas, part of this water would freeze causing the ground to heave. This problem could be solved by maintaining the temperature of the gas near the ambient temperature. This would be difficult, however, because gas would be chilled only at compressor/refrigeration stations along the route, and consequently, its temperature would vary between stations. 2) Heaving and development of icings at the surface caused by freezing of ground water in shallow aquifers. 3) Liquefaction, slope instability, differential settlement, and erosion caused by the thawing of ice-rich soils during the interval between the time of burial and the operation of the pipeline. 4) Heaving caused by seasonal freezing of thawed, frost-susceptible soils in and adjacent to the trench.

After the pipeline serves its purpose and the transmission of gas stops, man-made permafrost would be subject to thawing, which could cause serious environmental effects including soil liquefaction, mudflows, landslides, differential settlement, disruption of surface- and ground-water drainage, and erosion.

Disturbances Caused by Construction and Operation of Pipeline South of 60° N. Latitude

The basic construction procedures for the proposed pipeline would be essentially the same both north and south of 60° N. latitude except that the special procedures required in permafrost areas would be required along only 150 miles of the proposed route south of 60° N. latitude. Most of the proposed route in Alberta, British Columbia, and Saskatchewan would be close to and parallel to existing pipelines and through areas where human development is widespread; compared to northern areas, terrain scars, new access and maintenance roads, and other primary impacts would not be as severe. River crossings in the plains could cause severe erosion, slope-instability, and siltation problems because of the widespread occurrence of potentially unstable shale bedrock.

Extraction of Natural Construction Materials and Resulting Terrain Scars

The impact caused by the excavation of borrow pits and rock quarries is limited mostly to terrain scars, drainage disruption, and slope instability. Problems arise in trying to assess the impact over most of the proposed route south of 60° N. latitude because the Applicant has not selected borrow and quarry sites south of Milepost 941.

Terrain scars caused by the excavation of borrow pits and rock quarries would be largely unavoidable. The undercutting of present slopes and the creation of steep pit slopes could result in local slumping. Shaping of the pit and side slopes would be necessary to control accelerated erosion and ponding, and to maintain slope stability. Excavation of borrow pits in the scattered areas of permafrost would result in thawing causing thaw subsidence and instability in ice-rich materials.

Disruption of Drainage

Drainage patterns could be disrupted in a variety of ways by a pipeline and the facilities necessary to construct, operate, and maintain it. Where buried in sloping terrain the proposed pipeline would generally interfere with existing surface and subsurface drainage where the pipe temperature would be kept below freezing and the pipe might develop a frozen annulus. This frozen envelope could impede the downslope movement of subsurface water and result in ponding on the upslope side. The resulting increase in load and decrease in strength of saturated surface materials could lead to slope instability and failure which could displace or damage the pipeline.

Ponding of surface drainage might divert flow to a low place along the right-of-way; overflow at the low point could erode the backfill mound and form rills or gullies downslope from the pipeline. Surface drainage might also be diverted parallel to the pipeline for some distance and cause erosion along the right-of-way.

Roads, airstrips, borrow pits, and other facilities associated with construction and maintenance of the proposed pipeline could disrupt surface and subsurface drainage and would be likely locations for ground icings during winter months. Ground icings would not only interfere with operation and maintenance of the pipeline, but could also cause new drainage patterns to develop and erosion to accelerate when the icings melt in the spring.

Instability of Slopes

About 90 percent of the proposed route traverses landscapes which slope 5 percent or less. Except for those cases involving disturbances of the permafrost regime, slopes of less than 5 percent tend to be stable regardless of the character of the underlying materials. Consequently, the proposed pipeline should have little impact on slope stability. Slopes greater than 5 percent occur along the remaining 10 percent of the proposed route; most of these are near stream crossings and, locally, may exceed 70 percent. These areas would be susceptible to slope failures which, if deep-seated, could displace, damage, or break the proposed pipeline.

Construction and maintenance of the pipeline and related facilities could significantly affect adjacent slopes. Slope instabilities could result from:

1) Undercutting and the resulting oversteepening of slopes during construction of roads, borrow pits, or the pipeline grade could result in various types of mass movements unless regrading slopes or other precautions are taken;

2) Redirected or ponded surface or subsurface water could increase slope load and decrease soil strength. If saturation causes elevated pore-water pressures, liquefaction leading to slope instability could result. Redirected drainage could also cause buoyancy problems which could damage the pipeline;

3) Thawing of permafrost due to disruption of vegetation or heat from buildings or other facilities could increase water content and decrease strength of surface materials; slope failures could possibly result;

4) Frost heave could affect the proposed pipeline and slopes marginal to it. Differences in texture, composition, and water content of soils could result in differential frost heave which could deform the pipeline along certain sections of the proposed route.

Accelerated Erosion

South of the 60° N. latitude, accelerated erosion could result from destruction of the vegetation cover, alterations of the local topography, or disturbance of sporadically occurring areas of permafrost.

The construction of the pipeline supporting roads and airstrips, as well as the removal of construction materials from borrow pits, could destroy or damage vegetation cover along the proposed pipeline route. The stripping of ground cover from weathered and unconsolidated materials could, in turn, result in very rapid erosion of rills and the formation of gullies on all but the most gentle slopes during times of surface runoff. Accelerated erosion would be more significant on steeper slopes and in wet areas where removal of vegetation would result in thawing of any permafrost that might be present.

The proposed pipeline would disrupt existing surface drainage systems wherever it crosses slopes. Concentrating surface and subsurface water into channels in order to direct it through culverts could result in accelerated erosion beyond the culverts due to locally increased discharge.

Stream crossings also present potential problems for pipeline construction and operation. Both vertical and lateral changes in channel shape and location can occur rapidly and are difficult to predict. Such changes would be especially significant because the Applicant plans to bury the pipeline at stream crossings. Unless burial depth exceeds the maximum depth of scour, the force of the current and the impact of boulders at times of high discharge could damage or even rupture the pipeline if it were exposed. Predicting the maximum flood and maximum depth of scour at each proposed crossing would be very difficult and would require a careful evaluation of each crossing.

Accelerated erosion and other unforeseen problems could be encountered if rivers and streams were diverted during burial of the proposed pipeline in river channels. The diversion process could alter drainage patterns, slope stability, and erosion rates. Removal of vegetation and disruption of bedrock and surficial units along steeply sloping river banks would certainly affect erosion and slope stability which could result in increased sediment load in the stream. The geology and hydrology of each stream and flood plain to be crossed by the proposed pipeline would require detailed study prior to final design.

Thawing of Permafrost and Effects of a Cold Buried Pipeline

The southern limit of the discontinuous permafrost zone lies about 150 miles south of the 60° N. latitude. Within this zone, permafrost occurs in isolated patches and is relatively "warm"--slightly colder than 32° F. Its patchy distribution makes the presence of ice-rich permafrost difficult to predict, and its warm temperature makes the permafrost very sensitive to surface disturbances and to being thawed. Ice-rich fine-grained permafrost soils, when thawed, undergo a change in volume and a loss of strength. The resulting differential settlement of the ground surface and the instability of soils could pose major environmental and engineering problems.

For the first 37 miles south of the 60° N. latitude, the gas would be 32° F during the first 4 years of operation (CAGPL, 1974c, 17.2.1(b), p.2). A cold buried pipeline could cause serious engineering and environmental problems. These problems were discussed under "Thawing of Permafrost and Effects of a Cold Buried Pipeline" north of the 60° N. latitude.

Distribution of Potential Geologic Impacts Along the Route

Engineering Geology Evaluation Categories

To provide a component for the system of analysis that will be developed in this section, it is necessary to categorize the geologic materials, bedrock and the overlying surficial deposits, according to their physical properties. Such a categorization permits an evaluation in terms of their engineering-geologic characteristics. For the present purpose, a very simple classification divides the bedrock formations into three classes, comprising respectively rocks that may be termed hard, moderately hard, and soft. Hard rocks are those with the highest bearing capacities, able to carry loads imposed upon them by all engineering projects, and able to stand firmly in steep slopes. Such rocks may have zones of weakness along faults and joints, but they are sufficiently widely spaced that they do not present problems except in a very small proportion of the area underlain by these rocks. Soft rocks have lower bearing capacities that may present foundation problems, and are not stable in relatively steep slopes. Some of these rocks present other problems; for example, they may contain minerals that swell or shrink with changes in moisture content of the rock. Moderately hard rocks form an intermediate class that generally contains mixtures of hard and soft rocks or rocks whose properties are intermediate between the two.

Surficial deposits that overlie bedrock have generally lower bearing capacities than most bedrock units, but they are considerably easier to excavate for engineering purposes. Because of their widespread occurrence at the surface of the earth they form the materials on and in which much construction takes place. Coarse-grained deposits such as gravel and sand, and diamicton that contains more gravel and sand than silt or clay have sufficient bearing capacity that they do not present serious problems for many engineering purposes. Silt and clay and organic deposits may have very low bearing capacities, are generally unstable on even moderately steep slopes, and thus are the most problematical materials for engineering purposes.

Because the analysis must evaluate the surficial deposits, which cover most of the route of the pipeline, and the bedrock, which underlies them at varying depths and is exposed principally on relatively steep slopes near stream crossings, the engineering-geology categories used here consist of a combination of units of bedrock and surficial deposits. The various possible combinations have given rise to the following four categories, listed with a brief evaluation of their potential for presenting engineering-geology problems:

A. Hard rocks without overlying surficial deposits. These rocks present relatively few problems other than requiring blasting for excavation.

B. Moderately hard rocks without overlying surficial deposits; hard and moderately hard rocks overlain by coarse-grained surficial deposits. Minor problems may occur in some places, but generally bearing capacities are high and slopes are stable. Especially where surficial deposits are present, these materials present fewer problems of excavation than do the rocks in category A.

C. Soft rocks without overlying surficial deposits, or overlain by coarse-grained surficial deposits; hard to moderately hard rocks overlain by fine-grained surficial deposits. These combinations of materials may present significant problems because of low bearing strength in places, and may give rise to instability on slopes. There may be wide variations in physical properties, so that some areas may have significantly greater engineering-geology problems than others.

D. Soft rocks overlain by fine-grained surficial deposits; fine-grained surficial deposits of sufficient thickness that the underlying bedrock, regardless of its nature, is not a significant factor in determining the extent of engineering problems. This represents the worst possible combination of geologic materials, with low bearing capacities common and instability prevalent on most slopes.

Combinations of groups or units of bedrock and surficial deposits with similar engineering-geology characteristics which occur along the route of the pipeline have been placed into the engineering-geology categories shown in Table 3.1.2.3-1; most combinations fall into the two lower categories C and D.

Table 3.1.2.3-2 shows the distribution of the four engineering-geology categories along each of the six major parts of the route, and Table 3.1.2.3-3 summarizes this distribution and gives percentages of each of the categories for each part and for the entire route. The categories are present along the routes in roughly inverse proportion to the quality of materials that they represent, that is, the least problematical rocks and surficial deposits are absent in most places, and the combinations most

Table 3.1.2.3-1 Engineering geology categories into which combinations of bedrock units and surficial deposits units found along the proposed route have been placed

	Bedrock			
	Hard	Moderately hard	Moderately hard to soft	Chiefly soft
Surficial deposit (estimated thickness in feet where available)	Precambrian quartzite and argillite	Paleozoic sedimentary rocks of various kinds	Devonian & Tertiary sandstone, conglomerate, and shale	Devonian & Cretaceous shale with minor sandstone; Cenozoic gravel, sand, and silt
None	A	-	B	-
Gravel, sand (0-10)	B	B	B	C
Gravel, sand (20-30)	B	B	B	C
Gravel, sand, diamicton	B	-	B	C
Gravel, sand, diamicton, silt, clay	-	-	C	C
Diamicton				
(0-10)	B	-	C	C
do (10-20)	-	-	-	C
do (20-50)	-	-	C	C
Sand (20)	-	-	C	C
Sand, silt overlying gravel	-	-	-	C
Sand overlying silt, clay	-	-	D	D
Silt-clay rich diamicton				
(0-10)	-	C	-	D
do (10-20)	-	-	C	D
do (20-40)	-	-	D	D
Silt, clay (0-20)	-	C	D	D
do (20-50)	-	D	D	D
Silt, clay overlying gravel or diamicton	-	-	D	D
Organic material (10-20) overlying gravel, sand, diamicton, or silt-clay	-	-	-	D

Table 3.1.2.3-2 Distribution of engineering geology categories along the proposed route

Locations are by mileposts; lengths in miles.

A		B		C		D	
Location	Length	Location	Length	Location	Length	Location	Length
		Prudhoe Bay Supply Line					
		195-205	10	205-225	20	225-252	27
				252-277	25	277-305	28
				305-330	25	330-415	85
				415-492	77		
		Richards Island Supply Line					
				32-57	25	0-32	32
				125-143	18	57-125	68
				10-15	5	0-10	10
		Main Line north of 60° N Latitude					
		284-288	4	126-146	20	146-174	28
		365-414	49	174-187	13	187-266	79
				266-284	18	318-338	20
				288-318	30	340-358	18
				338-340	2	440-551	111
				358-365	7	552-553	1
				414-440	26	555-565	10
				551-552	1	601-683	82
				553-555	2	723-821	98
				565-601	36		
				683-723	40		
		Main Line south of 60° N Latitude					
		1290-1292	2	1240-1251	11	821-1240	420
				1256-1263	7	1251-1256	5
				1292-1308	16	1263-1290	27
				1390-1423	33	1308-1390	82
						1423-1430	7
		Monchy Delivery Line					
		1-2	1	65-82	17	0-1	1
		8-10	2	136-151	15	2-8	6
		14-16	2	215-228	13	10-14	4
		38-39	1	274-296	22	16-38	22
				336-350	14	39-65	26
				360-394	34	82-136	54
						151-215	64
						228-274	46
						296-336	40
						350-360	10
		Kingsgate Delivery Line					
195-215	20	10-13	3	20-114	94	0-10	10
231-239	8	114-147	33	147-152	5	13-20	7
248-253	5	152-195	43				
		215-231	16				
		239-248	9				
		253-281	28				

Table 3.1.2.3-3 Summary of engineering geology categories along the proposed route

	A		B		C		D	
	Miles	% of route	Miles	% of route	Miles	% of route	Miles	% of route
Prudhoe Bay Supply Line	-	-	10	3.4	147	49.5	140	47.1
Richards Island Supply Line	-	-	-	-	48	30.4	110	69.6
Main Line north of 60° N Latitude	-	-	53	7.6	195	28.1	447	64.3
Main Line south of 60° N Latitude	-	-	2	.3	67	11.0	541	88.7
Monchy Delivery Line	-	-	6	1.5	115	29.2	273	69.3
Kingsgate Delivery Line	33	11.7	132	47.0	99	35.2	17	6.1
Totals	33	1.3	203	8.3	671	27.6	1528	62.8

likely to present problems are the most widespread, categories C and D together occurring on about 90 percent of the route.

Permafrost Categories

Permafrost categories (W,X,Y and Z) were established and described in Section 2.1.2.3.

Table 3.1.2.3-4 shows the distribution of these permafrost categories by miles along the entire proposed route, and Table 3.1.2.3-5 summarizes this distribution for each of the major parts and for the entire route. The two categories, Y and Z, which represent permafrost conditions that can cause the most severe construction problems, dominate the two northern supply lines, occurring along 80 to 90 percent of their routes, but occupy only about 50 percent of the Main Line north of the 60° N. latitude. They are expected absent to the south, where there is very little permafrost.

SPG Index

An index, here termed the SPG Index, has been devised to combine the evaluations of the three elements (slopes, permafrost, and geology) that have the most important bearing on engineering-geologic problems anticipated along the route. The index is the sum of three components, the values of which are assigned to the categories of slope (sections 2.1.2.2 and 3.1.2.2), permafrost, and engineering-geology evaluation previously established in this statement. The index can be interpreted as a measure of potential geologic impact, and thus can be used to present in a simplified and generalized way the potential impacts on the environment and on the pipeline that are related to geologic materials (including engineering soils) and conditions along the route on a mile-by-mile basis.

The numerical values associated with each category of each element are shown in Table 3.1.2.3-6. The values chosen are based on a nearly even distribution of weights among the three elements, and among the categories of each element; that is, it is assumed that each element is of equal importance in contributing to an engineering-geologic problem and that successive categories of each element represent a successively greater contribution to creation of such a problem in a succession that has roughly equal increments. These assumptions may not prove ultimately to be entirely correct, but as a first approximation they are considered appropriate. As a check on the validity of these assumptions, combinations of slope and geology categories previously evaluated were compared with the interpretation made from SPG Index values. The two evaluations were found to be nearly coincident; minor adjustments to SPG Index component values were made to make the coincidence more nearly perfect.

The SPG Index ranges in value from 0 to 10. It is generally expressed as integers, the sums of the index component values being rounded to the nearest integer, but some half-integer steps are also used. A value of 0 represents essentially no expected geologic problems and thus minimal potential impact, and a value of 10 represents a combination of elements giving rise to the most severe geologic problems and thus maximal potential impact. Index values have been grouped into classes that represent categories of potential geologic impact as follows:

Table 3.1.2.3-4 Distribution of permafrost categories along the proposed route

Locations are by mileposts; lengths in miles.

W		X		Y		Z	
Location	Length	Location	Length	Location	Length	Location	Length
Prudhoe Bay Supply Line							
		200-203	3	465-492	27	195-200	5
		221-224	3			203-221	18
		405-407	2			224-405	181
						407-465	58
Richards Island Supply Line							
		10-19	9	25-31	6	0-10	10
		31-47	16	129-143	14	19-25	6
				0-15[1]	15	47-129	82
Main Line north of 60° N Latitude							
599-600	1	130-145	15	126-130	4	150-162	12
713-727	14	177-187	10	145-150	5	187-216	29
738-741	3	258-301	43	162-177	15	304-320	16
760-788	28	337-358	21	216-258	42	331-337	6
792-798	4	365-371	6	301-304	3	414-420	6
		571-580	9	320-331	11	477-571	94
		582-595	13	358-365	7	580-582	2
		600-646	46	371-414	43		
		658-713	55	420-477	57		
		727-738	11	595-599	4		
		741-760	19	646-658	12		
		788-792	4				
		796-821	25				
Main Line south of 60° N Latitude							
874-896	22	821-874	54[2]				
903-933	30	896-903	7				
945-956	11	933-945	12				
957-1430	473	956-957	1				
Monchy Delivery Line							
0-394	394						
Kingsgate Delivery Line							
0-137	137	137-140	3				
140-155	15	155-156	1				
156-165	9	165-167	2				
167-195	28	195-196	1				
196-198	2	198-207	9				
207-250	43	250-251	1				
251-281	30						

---

[1] Parsons Lake Lateral Line.

[2] Milepost designations 863.4 through 864.8 occur twice because of alinement change.

Table 3.1.2.3-5 Summary of permafrost categories along the proposed route

	W		X		Y		Z	
	Miles	% of route	Miles	% of route	Miles	% of route	Miles	% of route
Prudhoe Bay Supply Line	-	-	8	2.7	27	9.1	262	88.2
Richards Island Supply Line	-	-	25	15.8	35	22.2	98	62.0
Main Line north of 60° N Latitude	50	7.2	277	39.9	203	29.2	165	23.7
Main Line south of 60° N Latitude	536	87.9	74	12.1	-	-	-	-
Monchy Delivery Line	394	100	-	-	-	-	-	-
Kingsgate Delivery Line	264	94.0	17	6.0	-	-	-	-
Totals	1244	51.1	401	16.5	265	10.9	525	21.5

Table 3.1.2.3-6 Components of the SPG Index

This table lists categories of slope, permafrost, and geology, the index components of one of each type of which are added together to form the SPG Index

Type of Category	Symbol	Brief description		Index Component
Slope	G	Nearly flat to gently	(0-5%)	0
	M	Moderate	(5-10%)	0.8
	R	Moderately steep	(10-25%)	1.6
	S	Steep	(25-70%)	2.5
	V	Very steep	(> 70%)	3.3
Permafrost Conditions	W	Permafrost absent		0
	X	Low ice content	(< 20%)	1.2
	Y	Moderate ice content	(10-40%)	2.3
	Z	High ice content	(> 30%)	3.3
Engineering Geology	A	Hard rocks		0
	B	Moderately hard rocks; coarse-grained surficial deposits overlying hard to moderately hard rocks		1.1
	C	Soft rocks; coarse-grained surficial deposits overlying soft rocks; fine-grained surficial deposits overlying hard to moderately hard rocks		2.3
	D	Fine-grained surficial deposits overlying soft rocks		3.4

SPG Index	0-2.5	Low	Segments of route least likely to have any geologic impacts other than those of a minor nature.
	3-4.5	Moderate	Segments of route likely to have geologic impacts in only a few places. Some of these impacts may be of major import, but most are likely not to be.
	5-6.5	High	Segments of route likely to have geologic impact in many places. Many of these impacts are likely to be major in nature.
	7-10	Very High	Segments of route that could have geologic impacts everywhere. Most such impacts are likely to be major in nature.

This system presents what has been termed a "worst case" analysis; that is, it describes the potential for the most severe engineering-geology problems that are likely to develop, and thus the worst impacts that could occur. It does not predict that impacts will occur at every place along the segment of route as categorized, but it does give a measure of the degree to which various levels of impact are expected. It thus points out the degree to which engineering-geology problems need be considered in the design of the project so that potential impacts can be mitigated.

In a more general way the SPG Index could be translated (by dividing by 10) into a number that expresses, if crudely, the probability of occurrence of geologic problems. It would take much application of and experience with such an index to determine the accuracy with which such a translation could be made, and (or) to modify component values of the index to refine the correspondence between index value and actual probability. As a first-order approximation, however, it may be useful for this purpose now.

Figures 3.1.2.3-1 through 3.1.2.3-6 show the distribution of the SPG Index along the entire route on a mile-by-mile basis. They also show the potential impact category into which each part of the route is thereby placed. Stream crossings have been added, both to indicate graphically their location and distribution, and to illustrate the close correlation between stream crossings and increase in potential for geologic impact. The locations of some other features are shown for general reference.

The exact shape of the graph, which generally has long flat stretches broken by short peaks, is the result not only of the distribution of the natural conditions portrayed by the graph, but also of the differences in detail of the data that went into the making of the SPG Index. Generally, the long smooth parts of the graph result from a combination of permafrost and geology categories superimposed on the lowest category of slope, which has an index component of 0. The smoothness of these parts of the graph represents not only the true long stretches of nearly flat to gentle slopes, but also the lack of detail in the geologic and permafrost data available.

More detailed information would undoubtedly give these flat parts of the graph numerous wiggles both above and below its present position, identifying small areas of higher or lower ice content, or somewhat better or worse engineering-geologic characteristics. However, the departures from the flat position probably would not be more than one or two points on the index, and at most would raise or lower the graph to the next higher or lower impact category in some places, while the graph would remain in the same category in many other places.

The peaks of the graph correspond almost exclusively to the small lengths of slopes steeper than gentle, and the three most common widths of these peaks correspond to the three length categories used to delineate distribution of slopes (Tables 3.1.2.2-1 through 6 and 8 through 13). These peaks are approximately correct in height and horizontal position, and would change only in their vertical position if the "base line" provided by permafrost and geology categories were to move up or down by the addition of more detailed information on the distribution of those categories.

Table 3.1.2.3-7 summarizes the distribution of the SPG Index in terms of the classes of potential geologic impact for each major part of the route and for the entire proposed route in Canada. The two supply lines have their peak distributions in the very high and high impact categories, the Main Line north of the 60° N. latitude in the high and moderate categories, the Main Line south of 60° N. latitude and the Monchy Delivery Line in the moderate category, and the Kingsgate Delivery Line in the low impact category.

The table also provides an average SPG Index value for each of the parts of the route, and for the entire route. This average has been correctly weighted according to miles of route and index value as shown on the graph. The average values can only be used for purposes of gross comparison, but they do show that the northern supply lines have an overall rating in the high impact category, the Main Line in the moderate category, and the southern delivery lines in the low category.

The SPG Index graphs and the summaries show rather clearly that the northern lines have an overall potential for geologic impacts that is equivalent to or greater than the localized peak impact potentials of the more southerly lines. This is clearly because of the permafrost element. The Main Line and the Monchy Delivery Line have lower overall potential for impact; this overall level is as high as it is, however, largely because of the dominantly poor quality of engineering-geology characteristics of materials--shale and fine-grained surficial deposits--along much of these routes. The Kingsgate Delivery Line has the lowest SPG Index rating, and thus the lowest potential for geologic impact primarily because of the higher quality engineering-geology characteristics of the rocks along its route, in spite of the fact that it is also the most steeply sloping of the routes. The overall SPG rating of the entire proposed route in Canada falls in the higher part of the moderate impact category, which seems to be rather high for an overall rating. However, because of permafrost in the north, and relatively poor geologic materials both in the north and on the plains, this evaluation is probably an accurate reflection of the real situation.

Earthquakes and Active Faults

The proposed route in Canada has been divided into segments according to maximum expected earthquakes.

Table 3.1.2.3-7 Summary of SPG Indices for each major part and for the entire proposed route

SPG Indices are grouped into classes that are described in terms of potential geologic impact

Range of SPG Index	0 - 2.5		3 - 4.5		5 - 6.5		7 - 10		Index Value[1/]
Potential geologic impact	Low		Moderate		High		Very High		Average SPG
	Miles	%	Miles	%	Miles	%	Miles	%	
PBSL	3.0	1.0	9.9	3.4	141.1	47.5	143	48.1	6.6
RISL	-	-	15.4	9.7	57.6	36.5	85.0	53.8	6.2
ML-N	16.6	2.4	186.3	26.8	354.7	51.0	137.4	19.8	5.1
ML-S	58.8	9.6	465.8	76.4	83.2	13.6	2.2	.4	3.3
MDL	111.4	28.3	263.6	66.9	17.3	4.4	1.7	.4	2.7
KDL	226.8	80.7	45.0	16.0	8.8	3.1	.4	.1	1.9
Entire Proposed Route	416.6	17.1	986.0	40.5	662.7	27.2	369.7	15.2	4.1

[1/] computed by multiplying the number of miles of each whole or fractional index value by that index value, and dividing the result by the number of miles of route

Segment	Magnitude
Main Line and Supply Lines	
Alaska border to 138° W. longitude	5.5
138° W. longitude to Arctic Red River	7.0
Arctic Red River to 65° N. latitude	5.0
65° to 62° N. latitude	6.0
62° to 55° N. latitude	4.5
55° N. latitude to Caroline Junction	5.5
Kingsgate Delivery Line	
Caroline Junction to British Columbia-Idaho border	5.5
Monchy Delivery Line	
Caroline Junction to Saskatchewan-Montana border	4.5

The maximum expected earthquake is the largest earthquake that (on the basis of existing knowledge) may reasonably be expected to occur along a specified segment; it everywhere equals or exceeds the largest known historic earthquake. The zonation of the route might be further refined if more complete geologic and geophysical data were available.

No active faults have been identified along or adjacent to the proposed pipeline route; however, more detailed field investigations might reveal evidence for geologically recent movements, especially in areas that are seismically active.

The occurrence of large earthquakes (magnitude 6 or larger) is a potentially serious hazard to the integrity of the proposed pipeline--in fact, earthquakes of magnitude 5 may even cause local damage. Seismic shaking or surface faulting accompanying a large shock could rupture the pipeline directly or cause failure in the foundation material that could lead to rupture. Furthermore, earthquakes could trigger landslides which could jeopardize the integrity of the pipeline.

The applicant considers that the initial strength of ice-rich frozen soils would be a positive factor in restricting the adverse effects of earthquake-induced ground shaking (Alaskan Arctic Gas Company, 1974, Section 4.2.6).

Even though it is a remote possibility, rupture of the pipeline could cause a fire and (or) explosion, which in turn, could cause adverse impacts. In addition, any maintenance activity during the summer season in areas underlain by permafrost could cause significant permafrost-related adverse effects to the environment. See Overview volume, Section 3.OV.16 for further discussion of hazards to pipeline integrity.

Impact on Present and Future Mineral Resource Exploration and Production

Metallic and Nonmetallic Mineral Deposits

Other than local depletion of construction materials resources, the construction and operation of the proposed pipeline system should have little effect on mineral resource exploration and production except in the right-of-way itself and in areas dedicated to compressor stations and other ancillary installations.

Oil and Gas

The proposed gas pipeline through Canada would allow production of Canadian gas resources for which identified volumes seemed, until recently, insufficient for a transmission system independent of other supply. Without conservation regulations to restrict export of Canadian gas, the line should have little effect on production from the British Columbia-Alberta producing province. Exploration stimulated by the proposed pipeline should discover additional reserves of oil and gas; however, consumption of a non-renewable resource would be accelerated.

Seven trillion cubic feet of natural gas identified in the Mackenzie basin should be available for input upon completion of the proposed pipeline; almost certainly, exploration underway there will have substantially increased identified resources by that time. Substantial reserves in the southern Tathlina province are being produced through extensions of the present transmission system but production of other, unmeasured, gas resources discovered there await transport availability (de Wit and others, 1973, p. 209).

Access provided by the proposed pipeline would hasten exploration in prospective basins along the corridor. Present control of exploration areas by access is evident in the concentration of activity along waterways; the delta region of the Mackenzie basin has a well density of one per 260 square miles along the river whereas the well density is one per 8,720 square miles away from the river, in the northern District of Mackenzie (Table 2.1.2.3-1). If the pipeline were built, prospecting and drilling would probably begin along the proposed route and later spread to more remote prospective areas as reserves are discovered and developed.

Gas reserves several times those now identified would probably result. The volume of gas ultimately recovered would also be increased because some small discoveries would be produced because of a pipeline largely amortized by other reserves.

3.1.2.4 Soils

This section discusses the soil-related impacts that will occur as a result of constructing the proposed pipeline. Although quantifications, because of the lack of detailed information, are not possible the relative impacts anticipated and the ranges of effects to be expected are discussed.

Of all the agricultural resources affected by the proposed project the disturbance of the soil will create the most significant impacts.

Development of soils, particularly in the Arctic or northern Canada, is very weak or shallow and varies extremely within short distances. There is a distinct difference between the depth of soil development and the depth of unconsolidated surface materials or the regolith.

In addition to impacts on the construction site there will be offsite disturbances from the excavation of bedding materials and disposition of surplus materials from the pipeline trench. The quantities or quality of these materials cannot be assessed until construction begins or detailed surveys are made.

Descriptions of soil properties likely to be encountered along the pipeline route are contained in Table 2.1.2.4-2. The quantity of each soil limitation factor which will be encountered by the pipeline is unknown.

Contamination of Topsoils by Excavation of Subsoils

As described in Section 2.1.2.4, the pipeline will cross many types of soils with varied surface and profile characteristics. Trenching and other pipeline construction activities will impact soils in varying degrees ranging from complete burial to partial mixing of the topsoil with subsoils.

The Applicant's statement indicates that topsoil will be stockpiled and returned to the surface of the trench only in certain areas where stipulated by the landowner or others. Therefore, the total acreage where topsoil will be stockpiled and preserved is unknown. If topsoils are not stockpiled and respread, establishment of vegetation will be slow and difficult. In agricultural areas, if topsoils are buried or mixed with subsoils, crop production will be reduced for a period of time. The severity of this impact on crops or native vegetation will depend on the nature of subsoil material left on the surface.

Disturbing the topsoil and organic mat will affect the depth to permafrost. This will cause a decrease in soil stability, resulting in differential settling as well as potential mass movement, and will create ponding and/or channeling of surface waters. In both permafrost and nonpermafrost areas, disturbance of topsoils will greatly increase the susceptibility of the soil to wind and water erosion.

Disturbance of the soil will also have an effect on the natural plant communities.

Compaction and disturbance of the topsoil will occur on about 43,060 acres. Mixing of the topsoil and subsoil will occur in the actual trenched area for a distance of 2,435 miles involving approximately 2,361 acres.

Exposure of Wind and Water Erosion

Construction of the proposed pipeline will cause impacts on the productivity and physical qualities of the soil. Disturbance alters the soil structure, chemical characteristics, microbiological activity, soil-climate relationships, and plant communities which have been established over a long period of time. These kinds of changes increase the susceptibility of the soil to wind and water erosion.

The most severe erosion impacts will occur in areas of most disturbance. The wind erosion hazard is generally greatest in areas of sandy and silty soils. Wind erosion will cause local air pollution. Water erosion will cause sedimentation pollution in nearby lakes and streams. The actual amounts of soil loss and damage will depend on weather conditions and the conservation measures applied. Table 2.1.2.4-2 lists soil characteristics that help evaluate the potential hazards from wind and water erosion.

Approximately 43,060 acres of soils will be affected by construction activities.

Disruption of Agricultural Activities

The disturbance of cropland, primarily in Alberta and Saskatchewan, due to pipeline construction will cause two major adverse impacts: the loss of crops during construction and the reduction of soil productivity. If topsoil is stockpiled and replaced and soil compaction is not severe, crop production will be nearly normal the year following construction.

In addition to crop reductions, the pipeline construction activities will create a variety of inconveniences for the farmer. Movement of farm machinery and tillage and harvesting operations will be complicated by the trenching through established fields. Compaction or subsidence of fill areas along the trench and the exposure of cobbles or gravel on the surface will all contribute to more difficult farming operations.

Grazing and pasture land will be out of production during the construction year and will produce at a reduced rate until new vegetation is reestablished.

3.1.2.5 Water Resources

Impact on Surface Water

Surface Water Flow

The proposed pipeline route is over 2,400 miles long and crosses more than 960 stream channels, including ephemeral and perennial streams. Construction of the pipeline will alter the surface water environment. The degree of the potential impact will depend upon the design and the measures taken during construction to minimize the impact. Four areas of concern are: (1) channel erosion, (2) icings, (3) depletion of streamflow during construction and (4) drainage disruption.

Channel Erosion

Erosion resulting from diversion of streamflow or from excavation or constriction in the natural stream channel will be accelerated during pipeline construction. Removal of vegetation, trenching and backfilling will reduce the natural cohesion of banks, especially in ice-rich permafrost soils, with resultant increased erosion until these sites are stabilized or vegetation is reestablished (for more detailed discussion on ice-rich permafrost soils refer to Tables 3.1.2.3-4 and 3.1.2.3-5). Excavation and constrictions in the channel can increase stream velocities and turbulence and change the direction of flow, thus causing undesirable erosion on the channel banks and beds. Structures, such as spur dikes, jetties, and cofferdams used in temporary or permanent channel diversions will have unpredictable short term effects on the natural channel. The effects of flow diversion will be most noticeable just downstream from the structures. Some basic hazards are: (1) severe channel scour, (2) erosion that could cause water-quality degradation by increasing the concentration of suspended sediment in transport, and (3) erosion in the riparian lands of the floodplain. Channel erosion can be gradual, as during medium and low flows when the location of the channel may shift slowly as a result of stream meandering and braiding, or rapid, as during flood when scour tends to increase the size of the channel. In permafrost, channels may be enlarged by thawing and slumping of ice-rich banks. Undercutting of banks by streamflow may result in bank slumps or slides and rapid erosion. Ice and debris jams will often concentrate streamflow so as to cause rapid erosion or conversely in some cases cause a reduction in water conveyance and thereby increase the flood level. Where rapid channel erosion occurs, the concentration of sediment in transport commonly increases temporarily. Substantial increases in concentration and eventual deposition of sediment downstream will influence adversely at least parts of the aquatic biota. The major river crossings are listed in Table 2.1.2.5-1. Additional information on slopes, permafrost, geology and location is shown in Figures 3.1.2.3-1 through 3.1.2.3-6.

Icings

Icings alter surface-water flow in many ways; construction or development activities that alter the landscape increase the probability of icings which will affect both overland runoff and streamflow. For example, temporary construction roads or berms that cross actively forming icings will act as barriers. These barriers or dams will often increase the size and thickness of an icing to the point that the spring breakup flows will be diverted away from normal channels. The redirected flow may pass over land on material less resistant to erosion than the original natural streambed and cause new channels to form. An increase in the size of the icing may destroy the underlying vegetation. The removal of plant cover will change the thermal regime of any underlying permafrost thus increasing the thaw rate of surficial material (Brown and others, 1969). All of these changes, in cyclic fashion, affect the potential for the formation of further icings and may have an adverse effect on the habitat.

River icings may occur on streams of all sizes although they are generally more prevalent in shallow channels such as those of braided rivers. Rivers that flow continuously because of ground water or springs may be subject to extensive icings throughout the winter. For example, change in the insulating cover on the ice of a stream has been known to cause the stream to freeze to the bottom, thus forcing the flow to surface and leading to a river icing about six feet thick within a week (Thomson, 1963, cited in How,1974, p.7).

> "The icing will effectively raise the level of the river channel with the result that the flood stages may be considerably higher than the same discharge would create in an ice-free channel. It is, unfortunately, not possible to accurately predict the rivers on which icings will be formed and the severity of the icings. However, on the basis of the occurrence of natural river icings along the Coastal Route and between Travaillant Lake and Ochre River, it is realistic to anticipate intensified icing activities along these sections." (How, 1974, p. 10.)

Ground icings are seldom encountered under natural conditions. But, in areas where natural conditions have been disturbed by man, they become the predominant icing type (Ghiglione 1948, Chekotillo 1960, cited in Environment Protection Board, 1974, Research Reports, Vol. IV, p. 7). It is most common for icings to develop from ground water above the permafrost zone or some other impervious material at shallow depths.

Depletion of Streamflow During Construction

Large quantities of water will be required during construction for such purposes as ice roads, pressure testing, ditch flooding and camp facilities (CAGPL, 1974b, 6.3.4, p. 9). Compressor stations will require a lesser amount of water for cooling and domestic purposes.

In the permafrost areas an undetermined amount of water will be required for the construction of temporary ice and snow roads. The estimated usage of water according to the Applicant is shown in Table 3.1.2.7-4. An adverse impact will result if amounts of water are withdrawn to the extent that the normal low flow pattern of the stream is disturbed. If the withdrawal of water alters this pattern, then it can be expected that much of the aquatic biota will be destroyed.

In permafrost-free regions, water will be used as a liquid-test medium. It is difficult to assess the possible impact on surface water flows and channel erosion unless some estimate of the amounts of water required is made and unless it is known where and how the water will be discharged. Test water per mile of full 48-inch pipe would be about 66,000 ft^3; uncontrolled release of that volume of water from pipe laid on almost any slope would cause severe channel scour if discharged into small streams that do not have adequate channel capacity. It should be noted here that more than 1,000 of the streams crossed have drainage areas of less than 300 sq. mi.; many of these small streams are classed as ephemeral, and may not have the channel capacity to carry the uncontrolled release of test water.

Drainage Disruption

Construction activities can disrupt drainage patterns, particularly the smaller drainage patterns, and diversions of streamflow or overland flow can result from damming or trenching. This disruption or diversion will result in the concentration of flow at higher velocities resulting in a greater erosion potential.

Damming of surface drainage along the proposed project by (1) pipeline berms, (2) roads, (3) airstrips, (4) compressor station pads, (5) equipment storage areas, (6) flood protection dikes, and (7) icings are examples of threats of accelerated erosion and resulting alteration of the landscape.

Drainage diversions resulting from trenching can be expected to initiate new erosion patterns. Subsidence would most likely be due to thawing of ice-rich permafrost wherever the vegetative ground cover is disrupted (Brown and others, 1969). Surface subsidence in ice-rich permafrost adjacent to the proposed pipeline will occur and provide new drainage channels which will be subject to erosion.

Other examples of thermal change and related subsidence have been analyzed and documented along the trans-Alaska oil pipeline (Ferrians and others, 1969); at the Kelsey generating station, Manitoba (Johnston, 1969); accompanying Arctic engineering at Barrow, Alaska (Lewellen and Brown, 1969); and along highways and railroads in Alaska (Nichols and Yehle, 1961). Surface disturbance and thermal changes induced by oil exploration activity in the Mackenzie Delta area have caused sliding, slumping, and accelerated erosion of permafrost (Watmore, 1969). These examples provide data for concern about disturbing drainage patterns sufficiently to cause gullying.

The placement of chilled pipe in river channels and floodplains where there is permafrost will cause different effects from those in sections without permafrost. In places with permafrost, a chilled pipeline will reduce the depth of the active layer along the pipe relative to sections outside the influence of the frozen core. This reduced active layer acts as a dam which will cause ponding on level ground and will change flow patterns on sloping ground. The ponding of water will cause thermokarst subsidence and the changes in drainage will cause unstable conditions at the discharge point. During the winter months, ground icings will be developed along large sections of the proposed pipeline as the ground water trapped between the freezing surface and the permafrost is forced to the surface. One of the areas of concern extends from Mileposts 290 to 420; for other areas of permafrost refer to Table 3.1.2.3-5. In the sections of proposed pipeline right-of-way with no permafrost and in the discontinuous permafrost zones, the cold pipeline will form a frozen core. This core or dam will extend to greater depths with time. Lakes and ponds normally recharged from this zone could dry up slowly. The changes in drainage patterns can lead to unstable conditions in an area that is now considered stable. This situation is likely to be more severe south of Willowlake River (CAGPL, 1974a).

A summary of impacts is shown in Table 3.1.2.5-1.

Surface Water Quality

Major water-quality impacts which are apt to occur are (1) change in suspended-sediment concentration, (2) toxic elements from fuel spills, and (3) contamination from waste discharges. It is anticipated that the proposed pipeline will have no measurable effect on the dissolved-mineral content of surface water.

Change in Suspended-Sediment Concentration

Increases in suspended-sediment concentration will occur where channel and bank erosion is accelerated by the construction or operation of the proposed pipeline. Several sources of sediment will be created by pipeline construction. For example, at 40 waterways important to fishery resources (Table 3.1.2.7-1) additional sediment will be made available for transportation as a result of ditching, backfilling, dredging operations, and fording by vehicles.

At pipeline river crossings in permafrost zones, construction will be during the winter months when an undetermined number of streams will be frozen to the bottom or have icings. Some material excavated in trenching and pipelaying operations will be available for transport during the snowmelt-runoff period. At crossings where there is flow under ice cover, natural suspended-sediment concentrations are normally low. These streams will experience large increases in turbidity and suspended-sediment concentrations during pipeline construction. Although the distances the sediment will be transported downstream are not very great, the disturbance of any winter habitat of fish is detrimental (see Fishery Resources in Section 3.1.2.7 for additional information).

The spoil banks of unsuitable backfill material that are left on the ice or in stream channels will inhibit the natural flow patterns and cause problems of erosion and sediment deposition. Increases in sediment concentration caused by disturbance of river banks during construction will be temporary in most cases. However, increases of long-term duration will occur where deep cuts in the channel are required and where large cuts and fills are made in the flood plains during pipeline construction. Sediment concentrations greater than normal will continue until the cuts and fills are stabilized. This additional concentration of suspended sediment could occur downstream from some crossings for 2 or more years after the completion of pipeline crossings (U.S. Dept. of the Interior, 1972).

Many factors are involved in the subjective determination of the probability of significant impact by sediment transport and turbidity. Chief among these are the composition and particle-size distribution of bed and bank material, the streamflow characteristics, channel characteristics, natural levels of suspended-sediment concentrations and turbidity, stream biota, and construction practices. Field studies and special crossing-site examinations will be required before specific impacts of the proposed action can be accurately assessed.

Although the values of suspended-sediment concentration cannot be correlated directly with impacts on the basis of the data available, the range in concentrations will increase downstream from major crossings during construction. In some river reaches suspended-sediment concentration will temporarily be as much as 10 to 1,000 times greater than normal. Such increases in sediment transport and subsequent deposition downstream will

Table 3.1.2.5-1 Summary of impacts

Causal Factor	Mechanism of Impact	Possible Consequence	Severity of Problem
		Surface Water	
Drainage disruption			
Roads	Surface generally kept clear of snow. Results in greater frost penetration.	Occurrence of ground icings; can choke culverts. During thaw, diverted drainage can lead to channel erosion.	Localized icing problems. Access roads to the 108 borrow pits north of 60° N Latitude (table 3.1.2.6-2) may cause drainage disruption.
Airstrips	Surface generally cleared of snow. Results in greater depth of frost penetration.	Occurrence of ground icing.	Very localized problem. North of 60° N Latitude, 14 proposed airstrips and 56 helipads will contribute to drainage disruption (table 3.1.2.6-2).
River Crossings	Reduces cross-sectional area of flow in alluvium. Induces conditions favorable for river icing.	Freezing of the river to the bottom may affect aquatic life. Ice can encroach on nearby structures and communities. Icing can result in raised flood stage that may cause bank erosion.	Due to insufficient data and knowledge, effects are presently uncertain.
Chilled Pipeline	Reduces depth of active layer above pipeline. Increases depth of freezing and blocks groundwater flow at great depth.	Ponding, redirection of drainage that can cause new instabilities. Redirection of drainage can cause drainage of wetlands and instability of slopes.	Problems may be extensive particularly between Fort Norman and Fort Good Hope. Problems likely to be more severe south of Willowlake River.

Adapted from Environment Protection Board, 1974, Research Reports, Vol. IV, p. 18.

Table 3.1.2.5-1 Continued

Causal Factor	Mechanism of Impact	Possible Consequence	Severity of Problem
		Surface Water (con't.)	
Channel erosion			
Roads	Constriction at river crossings; concentration of flow by culverts.	Increased velocities and change in direction flow, bank slumps, etc.	Localized increase in suspended sediment; bank failure for indefinite time.
Airstrips & Compressor Stations	Change of drainage patterns notable across small drainage basins.	Thermal changes in active zone; development of thermokarsts, new channels.	Localized problem; major effect on small basins may be permanent impact on terrain downstream.
River Crossings	Removal of vegetation, excavations, trenching, and constrictions.	Reduction of natural cohesion in river banks.	Localized erosion of banks and channel; increased suspended-sediment transport.
Chilled Pipeline	Acts as barrier to subsurface flow.	Cause piping of flow along pipeline axis.	Impact unknown but believed to increase sediment transport.
Icings			
Roads	Increased frost penetration of active zone.	Blocked culverts and change of runoff to new channels.	Localized, but may have permanent effect on terrain (see drainage disruption above).
Airstrips & Compressor Stations	Disturbance of active zone, acting as a barrier to ground-water flow.	Change in thermal equilibrium; damage to vegetation.	Localized, but will have a permanent effect on small drainages.
River Crossings	Change in natural flow patterns because of changes in insulating snow cover.	Extreme ice jams, bank erosion.	Local, but serious, effect on bank stability.

Table 3.1.2.5-1 Continued

Causal Factor	Mechanism of Impact	Possible Consequence	Severity of Problem
		Surface Water (con't.)	
Icings (con't.)			
Chilled Pipeline	Increased river ice caused by presence of frozen core.	Extreme icing could cause flow to decrease or cease downstream from crossing.	Decreased flow could effectively destroy biota.
		Water Quality	
Roads, Airstrips & Compressor Stations	Gravel borrow and addition of organic material (petroleum products; wastes to streamflow).	Increased suspended sediment; oxygen depletion and destruction of biota; pollution of streams.	Localized and temporary except in extreme cases where impact may persist for two or more years.
River Crossings	Trenching and backfilling; dumping unsuitable backfill in streams.	Increased suspended sediment.	Localized; disturbance downstream not very great.
Chilled Pipeline	Spoil banks from trenching; toxic materials.	Increased suspended sediment transport distruction of biota.	Localized except for toxic material which may have effects for several months.
		Ground Water	
Roads, Airstrips & Compressor Stations	Compression of active layer; accelerated thermal degradation, due to removal of vegetative cover.	Icings, thermokarsts, quick conditions, slope failures.	Localized long-lasting change in terrain.
River Crossings	Effects on shallow aquifers by allowing flow along pipe in trench backfill material.	Trench cuts into alluvial train causing possible pollution.	Localized and temporary.

Table 3.1.2.5-1 Continued

Causal Factor	Mechanism of Impact	Possible Consequence	Severity of Problem
		Ground Water (con't.)	
Chilled Pipeline	Frozen core intersecting aquifer between surface and permafrost.	Drain water from unfrozen soil, possible frost heaves, thermokarsts.	Localized; may result in changes in terrain and groundwater aquifers for life of project.

influence adversely the aquatic biota. It is iterated, however, that absolute values of suspended-sediment concentrations are sensitive to many variables and only order of magnitude changes can be estimated.

Removal of gravel from streams or flood plains involving a half mile or more of river valley in some cases will have noticeable effects on the hydraulic characteristics of the stream, on the shape and form of the channel, and consequently will influence the biotic community of the area. The magnitude of the effects will depend on the rate at which the gravel is removed relative to the rate at which the stream is supplying similar sediment to the borrow area. If the turbulence and shear forces are changed as a result of gravel removal and exceed those which formerly existed, the stream regime would be changed, resulting in accelerated erosion and shifting of bottom materials (U. S. Dept. of Interior, 1972).

There are about 100 borrow pits north of 60° N. latitude from which about 30 million cubic yards of material will be extracted. There are more than 50 sites in the permafrost area that could be considered potential sources of impact on the water quality and drainage disruption. The Applicant has not selected borrow pits south of Milepost 941 except for one pit near Kingsgate.

All access roads to borrow pits whether temporary or permanent are expected to have an impact on drainage systems, icings, and water quality (suspended sediment).

The greatest potential for measurable increases in suspended-sediment concentrations is in streams in small steep watersheds that will have a large part of the drainage area disrupted by activities such as construction of airstrips, quarries, compressor sites, camps, roads, waste disposal sites, and pipeline rights-of-way. The greatest potential for major disturbance of natural stream processes is on the Arctic Coastal Plain, where large scale borrow operations have been suggested. (Howard, 1974.)

Prolonged increases in suspended-sediment concentrations would affect benthic invertebrates. Diversity indices may or may not be reduced, but species compositions of benthic invertebrate assemblages are likely to change to smaller organisms specifically adapted to fine-grained bottom material. The larger organisms which are usually the preferred fish food organisms will be greatly reduced in number (McCoy, 1974).

An increase in biological productivity can be caused by the addition of sediment containing organic matter. This, in turn, could cause an increase in biochemical oxygen demand and a lowering of dissolved-oxygen concentration. If sufficient organic matter including organic silts is deposited during the winter months, when dissolved oxygen is normally low, especially in subarctic and arctic streams, the additional oxygen demand will have a deleterious effect on the benthic fauna (McCoy, 1974). Along the proposed route, linear segments having surficial deposits that will yield similar sediments are identified by route Mileposts (see Section 2.1.2.3).

Introduction of Petroleum and other Toxic Materials

Large quantities of fuel oils, propane, methanol, and other toxic materials will be used during construction of the proposed pipeline. Many of the storage areas will be close to rivers and surface drainages. North of 60° N. latitude, there will be 22 fuel and material storage sites that will be sources of concern because of the introduction of petroleum and other toxic materials. Generally, these storage sites are associated with compressor stations. Although the greatest concern is north of 60° N. latitude, there should be concern for the southern portion of the line. The Applicant has not identified storage sites south of 60° N. latitude.

A methanol-water mixture will be used to test the proposed pipeline for leaks. Methanol is very toxic to humans; as little as 10 ml has caused death, and smaller amounts have caused permanent blindness (Stecher, 1968). Aquatic organisms are more tolerant of methanol, apparently being able to withstand 25 to 8,000 mg/l for 24 hours (M. M. Ellis in McKee and Wolf, 1963, p. 219). However, McMahon and Cartier (in Environment Protection Board, 1974, Vol. IV, page 229) found that both Arctic char and grayling fry could not tolerate exposure to greater than 1 percent methanol for 24 hours and that concentrations of over 2.5 percent were lethal in a much shorter time.

Serious problems to aquatic communities will result if petroleum products are spilled into any drainage system; petroleum products are toxic to aquatic life. McKee (1956) reported that these products are detrimental to aquatic organisms in the following ways: (1) free oil and emulsions may act on the epithelial surfaces of fish, thereby interfering with respiration, or may coat algae and plankton, thus removing sources of food, (2) oily substances that settle to the bottom may coat and destroy benthic organisms and interfere with spawning areas, (3) soluble and emulsified material may be ingested by fish and thereby taint the flavor of the flesh, or water soluble products may have a direct action on acquatic life, (4) organic material may deplete the oxygen in the water sufficiently to kill fish, and (5) heavy coatings on the water surface may interfere with aeration and photosynthesis. Some of these possible effects apply mainly to lakes; however, Bugbee and Walter (1973) found that distilled petroleum had the following effects in flowing water: (1) a fire hazard was immediately created, (2) fish and aquatic invertebrates were killed as far as 2 miles downstream from the spill, (3) gasoline residues prohibited the recolonization of mayflies, stoneflies, and certain caddisflies for at least 6 months, (4) mayflies and stoneflies were more sensitive than were some species of midges, (5) recovery of the contaminated stream reach was nearly complete after 12 months, (6) recovery was complete after 3 years, and (7) the persistence of gasoline residue in the streambed six months after the spill demonstrated the long-term hazards of a one-time point-source pollution event.

Nauman and Kernodle (in press) reported on the effects of fuel oil seeping into a small arctic stream for more than 2 years. The number of benthic invertebrates in all taxonomic groups was reduced in the immediate area of the oil seep. Bugbee and others (1974) found that aquatic invertebrates were affected within 3 weeks of a large single-point diesel fuel-oil spill. In the latter study, fuel oil initially combined with streambed sediment; the diesel fuel persisted in the sediment for 5 months but was not detected after 11 months. Furthermore, the toxicity had ceased after 5 months, as shown by recolonization of the contaminated areas by invertebrates.

The evidence indicates that petroleum spills and leaks are a threat to the aquatic environment, although the effect from small one-time spills will be minimal. Refined fuels, such as gasoline, are initially more toxic than diesel fuels. Long-term persistent leaks could result in total depletion of benthic invertebrates, thereby reducing the availability of fish food. One of the most critical areas will be along the Arctic coast region and on the Mackenzie River, where heavy barge traffic is proposed.

The proposed pipeline will be transporting methane, and it is assumed that accidental leaks from pipeline rupture or other pipeline failure can occur. Methane is not extremely soluble in water and should dissipate rapidly in an open-stream system in the case of a major pipeline rupture. Small leaks of long duration, if not detected, will add small quantities of methane to the water.

Little research has been done on the effects of methane on organisms in general, and no literature has been found on its effect on benthic invertebrates or plant life. V. E. Shelford and G. G. Schaut in reports published in 1917 and 1939, respectively, (cited in McKee and Wolf, 1963, p. 219) found that methane did not appear to be toxic or harmful to sunfish and that a saturated solution (65 mg/l) had no effect on minnows after a 2-hour exposure. Harder and others (1965) reported that methane in public water supplies may present a potential hazard. As little as 1 mg/l of methane in water at 74° F may create an explosive atmosphere in a confined space, such as a shower stall. If methane leaks occur in a proposed buried pipeline where it is intercepted by a shallow ground-water aquifer, a hazard could result if the water is withdrawn for a public supply.

Discharge of Wastes

Previous experience in pipeline construction in the Arctic indicates that although design criteria have been adequate, but not always followed; consequently, effluent from lagoons and temporary treatment systems has entered streams. The degradation of oxygen-consuming wastes may be much slower than in temperate zones, because there may be less oxygen available in some streams. Gordon (1972, p. 29) states that significant numbers of fecal indicator bacteria survive for an extended period in 0° C river water under total ice cover. Undoubtedly many villages along the pipeline route use raw water from rivers for drinking without treatment. Even small additions of wastes to these streams could create a serious impact on the water quality.

Impact of Proposed Pipeline on Ground Water

The primary impact on ground water by the proposed gas pipeline will be the disturbance of the shallow active zone overlying permafrost (suprapermafrost zone) during pipeline construction and operation. Disturbance of the thermal regime in this shallow zone will create new ground-water flow patterns resulting in icings, accelerated thermal degradation, accelerated erosion, frost heaving, and possibly explosive icing mounds. Another potential for impact on ground water will be the discharge of liquid wastes and the leaching of solid wastes in sanitary land fills. Although the Applicant proposes secondary treatment and sewage lagoons, it is of concern that any failure in the operation of the disposal system will be detrimental to the ground water resources. The leaching of solid wastes will add to the degradation of the shallow ground water sources. Finally, a minor and temporary impact on ground water will be its use for water-supply purposes during construction and operation of the proposed pipeline.

Ground-Water Flow

Ground icings on roads and related disturbances of the terrain are the result of the disruption of ground-water flow in the shallow, waterbearing layers caused by deepened seasonal freezing (Figure 3.1.2.5-1a). In the permafrost zones, the operation of a buried, chilled pipeline may form a frozen core or annulus around the pipe and if the core should intersect an aquifer, ground-water flow will be retarded. The disrupted ground-water flow will then surface locally to form icings (Figure 3.1.2.5-1b). It will

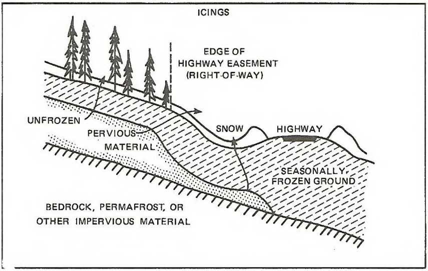

ICINGS
EDGE OF HIGHWAY EASEMENT (RIGHT-OF-WAY)
UNFROZEN
PERVIOUS MATERIAL
SNOW
HIGHWAY
SEASONALLY FROZEN GROUND
BEDROCK, PERMAFROST, OR OTHER IMPERVIOUS MATERIAL

Figure 3.1.2.5-1a A ground icing caused by a plowed highway. Deep seasonal frost penetration under the road dams the groundwater flow from upslope areas. Frost penetration is also deeper within the right-of-way due to reduced natural insulation. The solid arrows indicate possible paths of icing feed water to the surface. From Carey, K. L. 1973.

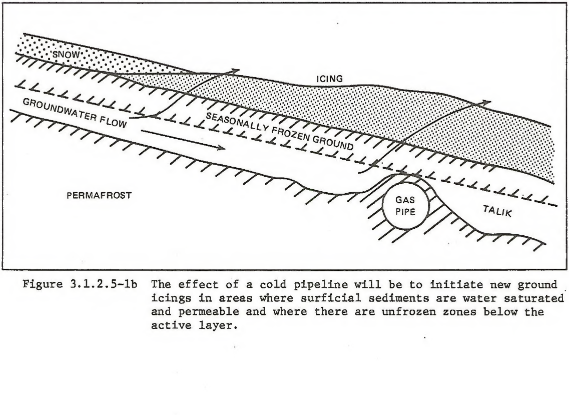


Figure 3.1.2.5-1b The effect of a cold pipeline will be to initiate new ground icings in areas where surficial sediments are water saturated and permeable and where there are unfrozen zones below the active layer.

also result in quick conditions, slope failures, and the formation of explosive icing mounds. Sidehill conditions will prove troublesome because ground-water movement is a direct function of the hydraulic gradient. In areas with gentle gradients, particularly in ice-rich soils, the damming effect of the frozen annulus around the pipe will impound water at or near the surface and accelerate the thawing of permafrost upslope from the pipe with consequent thermokarst development (Figure 3.1.2.5-2).

Where the proposed pipeline will be buried beneath streams, pipe and surrounding frozen core will reduce the volume of flow in the shallow aquifers. The effect will be greatest on smaller streams, particularly along the Arctic Coastal Plain and the east or right bank of the Mackenzie drainage, in some places sealing the aquifer to subsurface movement of water (Figure 3.1.2.5-3a). Although these phenomena refer mainly to the smaller streams, the icings will occur any place where the groundwater flow is effectively dammed from flowing in the normal downstream pattern.

In situations where an aquifer is near the freezing zone created by a chilled pipe, a process of ice aggregation will drain water from the unfrozen soil. As a result, an ice-lens growth beneath the pipe will occur and will tend to heave or jack the pipe upward (Figure 3.1.2.5-3b). These conditions could be expected near stream crossings where shallow aquifers are overlain by fine-grained confining materials. Frost heaves will also be more likely to occur in areas of discontinuous permafrost where the surficial materials are fine, silty soils.

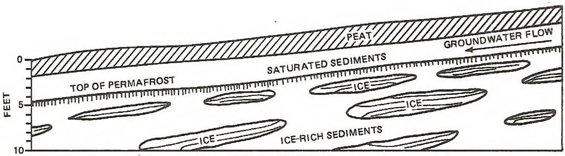
Areas with potential for detrimental frost heave are located mostly south of Willowlake River. Some small areas between Great Bear and Willowlake Rivers are also anticipated to result in frost heave problems (How, 1974, p. 17).

In areas with no permafrost, problems associated with shallow ground-water movement are likely to be less acute, except where the buried pipeline will cross stream channels or wetlands. At a river crossing, the pipeline trench will cut into the valley alluvium and its contained underflow. These sources of usable ground water must be protected against pollution.

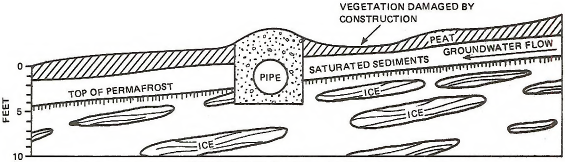
Ground-Water Quality

Information on ground-water quality in the Northern Region is limited; see Table 2.1.2.5-11 for a summary of chemical quality for selected springs and wells. Water from shallow wells in the permafrost zone is a calcium or magnesium bicarbonate type with low concentrations of dissolved solids and low total hardness. Ground water south of the permafrost zone is a calcium sulfate type water that is very hard and high in dissolved solids.

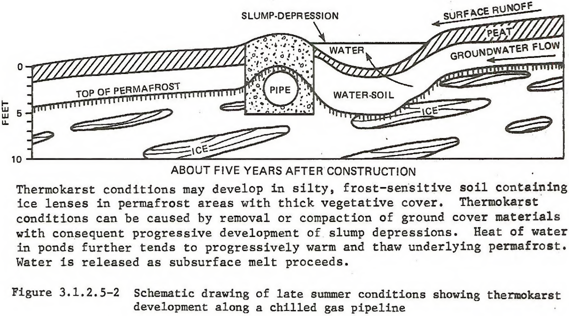
In general, construction, operation, and maintenance of the proposed pipeline should have little effect on the quality of ground water. However, any leaks of the methanol test liquid that enters the ground would be likely to contaminate ground water. Storage and handling of fuel during the construction phase which could lead to accidental spills will be apt to pollute the shallow ground water. Freeze-depressant solutions, such as glycol used in station heating systems, or other toxic chemicals that could also accidently spill will seep into the ground-water system. Sewage effluents which are subject to seeps from lagoons and ponds into the ground at camps and compressor stations, and buried solid wastes would be subject to leaching into the ground-water system. All the aforementioned potential impacts will be sources of pollution of the water.



BEFORE CONSTRUCTION



IMMEDIATELY AFTER CONSTRUCTION



ABOUT FIVE YEARS AFTER CONSTRUCTION

Thermokarst conditions may develop in silty, frost-sensitive soil containing ice lenses in permafrost areas with thick vegetative cover. Thermokarst conditions can be caused by removal or compaction of ground cover materials with consequent progressive development of slump depressions. Heat of water in ponds further tends to progressively warm and thaw underlying permafrost. Water is released as subsurface melt proceeds.

Figure 3.1.2.5-2 Schematic drawing of late summer conditions showing thermokarst development along a chilled gas pipeline

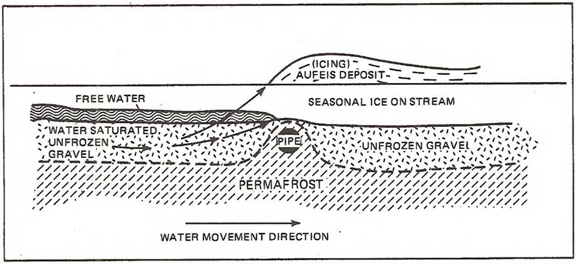


Figure 3.1.2.5-3a Aufeis deposits may develop where the pipeline crosses streams which are underlain by permeable saturated sediments (Schematic)

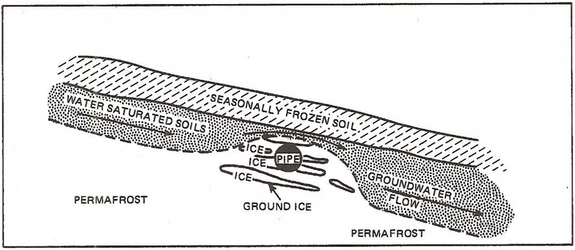


Figure 3.1.2.5-3b Ground ice may develop in vicinity of pipeline in areas underlain by fine-grained, silty soils. (Schematic)

Ground-Water Supplies

Ground water is not available for water supplies throughout most of the Northern Region because of permafrost conditions. Ground water is generally available in the Interior and Cordilleran Regions. Where the proposed route crosses streams, surficial deposits commonly consist of alluvium. These deposits are good aquifers where not frozen, and may contain large quantities of ground water.

South of the discontinuous permafrost zone, the potential yield from ground water is estimated at about 5,300 cfs (cubic feet per second), whereas the present ground water use is estimated to be about 75 cfs. In the Cordilleran Region, ground water supplies have not been extensively developed, but large quantities of water may be obtainable.

The largest demand for water will be in the construction of ice roads and for use as a test liquid in the proposed pipeline. Plans for water supply at camps and compressor stations are not detailed, but it is assumed that at least part of the water-supply needs will be met from ground water sources.

The total projected water supply needs for camp and compressor station uses are so small in comparison to the water resources available that the quantitative impact from ground-water withdrawal will be negligible.

3.1.2.6 Vegetation

Introduction

The principal effects of the proposed route for a natural gas pipeline on vegetation per se would be relatively straightforward. The primary, immediate, direct effect would be the removal of trees and tall shrubs from the right-of-way, and destruction of all vegetation on the ditch line and areas of work camps, compressor stations, communication facilities, wharves, stockpile sites, roads, airstrips, borrow pits and other ancillary facilities. The total land north of 60° N. latitude (Table 3.1.2.6-1) that would be committed to the project, amounting to over 20,000 acres, would be divided among many different functions, some temporary and some extending through the lifetime of the gas transportation system. Temporary activities, such as the actual construction of pipeline and facilities, and the longer period of occupancy and use of land, such as by permanent structures, roads and airstrips, would have adverse effects on vegetation for many years.

Not all of the planned activities would be totally destructive of vegetation even on the pipeline right-of-way and there would be many degrees of induced change to vegetation that would lie between total destruction, on the one hand, and minor disruptions on the other. There would be unavoidable effects on vegetation, as is true for all components of the environment and the ecosystems. The potential acreage losses of vegetation, amounting on the average to about 18 acres per mile north of 60° N. latitude, are not large in terms of the total available vegetation resource of the very large area of Canada that would be crossed. The more critical problems are concerned with the measures taken to avoid vegetation disruption that is avoidable; the care with which induced change would be confined to the right-of-way and immediate areas of all other facilities; and the restorative methods used which would present the opportunity for the natural recovery of vegetation in immediately possible cases, and eventually in all cases.

Table 3.1.2.6-1 Areas of vegetation formations affected by the proposed route in Yukon and Northwest Territories

	Pipeline Right-of-way	Compressor Stations	Communication Towers	Airstrips	Perm. Project Roads	Wharves, Stockpiles, Misc. Pads	Borrow Pits	Total
Prudhoe Bay Supply Line	4,409	219	33	730	132	234	433	6,190
Herbaceous Coastal Tundra	2,152	103	11	330	35	85	183	2,899
Forest-Tundra	2,257	116	22	400	97	149	250	3,291
Richards Island Supply Line	1,935	71	16	100	22	75	177	2,396
Low Shrub-Heath	894	29	5	100	22	73	109	1,232
Forest-Tundra	857	42	5	300	–	–	66	970
(Parsons Lake Lateral-Low Shrub-Heath)	184		6			2	2	194
Mainline-Travaillant Lake to 60° N Latitude	10,018	645	83	1,600	825	281	623	14,075
Forest-Tundra	2,778	255	28	775	203	111	153	4,303
Boreal Forest	7,240	390	55	825	622	170	470	9,772
Total	16,362	935	132	2,430	979	590	1,233	22,661

In assessing the potential impact of the project on vegetation only a single component of total environmental systems (the ecosystems) is under consideration. Although this simplifies the problem of evaluating impact, not only for vegetation but for other biotic and abiotic components treated in other sections of this Statement, it cannot be taken as a measure of impact on the most significant aspect of environment--the interrelationship and interdependencies of all parts of the system and the long-term secondary and tertiary effects that stem from the more visible primary causes of vegetation disruption (see Section 3.1.2.8).

Impact will be evaluated in terms of construction, operation, and ultimate abandonment of the proposed pipeline. The route will be considered in two geographic segments, that portion north of 60° N. latitude in the Yukon and Northwest Territories, and the part south of 60° N. latitude in the Provinces of Alberta, Saskatchewan, and British Columbia. This artificial division is one of convenience based upon the fact that the Applicant's environmental descriptions and impact analyses are so organized (CAGPL, 1974b, c) and a published environmental impact assessment (Environment Protection Board, 1974) is also available for the area north of 60° N. latitude. Bliss and Peterson (1973), Bliss and Wein (1972), and Wein and Bliss (1973) discuss the ecological impact of arctic construction, with emphasis on oil pipelines but most of the problems treated are applicable to natural gas pipelines. These authors cite the rather extensive literature that has evolved on northern environmental effects of pipeline projects.

The Yukon and Northwest Territories

Construction

During construction, as well as such preconstruction activities as surveying, test drilling, and right-of-way clearing, essentially every activity and every facility under construction would entail the potentiality for some degree of impact on vegetation.

Along the 120-foot right-of-way, when the line was fully powered, there would be 24 compressor stations, one every 40 to 50 miles. There would be stockpile sites, wharves, camp sites, communication stations, an airstrip at most compressor stations, access roads, hundreds of personnel, and huge quantities of transportation and construction machinery. Construction on gravel pads, plus the needs for gravel for airstrips, the few permanent roads that would be built, and for granular fill where required on the right-of-way, combine to an enormous requirement for a resource that is scarce in many parts of the far north. Many potential borrow pits have been identified and 108 of them, both on uplands and on fossil flood plains, have been designated for use.

The potential impact on vegetation of permanent construction is a major one since building sites for all purposes would require clearing and (or) grading and fill. Removal of materials, their transport and their use elsewhere, or their accumulation as spoil, would be destructive of vegetation. While much of this type of impact would be unavoidable, there would be many opportunities to reduce construction effects and the Applicant has specified protective measures to be employed (CAGPL, 1974b).

Impacts on Vegetation

Impacts off the right-of-way along the corridor occupied by the proposed route would be moderate to minor for a few years and relatively insignificant thereafter. Beyond the unavoidable, planned removal of vegetation, relatively few kinds of probable impacts appear to be of major or moderate concern.

With respect to impact on vegetation, this assessment follows the Environment Protection Board (1974, Vol. 3) which has defined a major impact as a "project component likely to disturb more than 5 percent of a plant community type in a region" and for this evaluation considered regional boundaries to be 10 miles on either side of the pipeline alignment or lesser distance where such major features as mountains, rivers, or lakes might form natural boundaries. A moderate impact was defined as one causing disturbance to 1 to 5 percent of a vegetation type.

A single vegetation component, "moss and peat integrity," was rated as subject to major impact as a result of a relatively large number of construction components. Major impact for this specific vegetation component was defined as one in which a "project component destroys the peat and moss mat or covers it with gravel such that little, if any, plant regeneration is possible." A moderate impact occurs when the mat is disturbed or compressed but is kept in place and "regeneration of existing plants is possible."

Pipeline Right-of-Way--North of 60° N. latitude 414 miles of right-of-way would cross the Forest-Tundra and 500 miles would cross the Boreal Forest. The right-of-way would occupy approximately 16,000 acres of land requiring clearing depending upon site conditions and the specific type of local vegetation. The general distribution of vegetation along the pipeline corridor is given in Table 3.1.2.6-2 for the area from Travaillant Lake to 60° N. latitude. Southward from the Forest-Tundra into the Boreal Forest there is a marked increase in the potential for right-of-way clearing as indicated by the increased percentage of mature riparian, hardwood, mixed wood and mature forest-tundra communities.

The Prudhoe Bay Supply Line would lie within the Herbaceous Coastal Tundra for 49 percent of its 297 miles and right-of-way clearing would be confined to tall shrub and mature riparian spruce forest communities at 13 river crossings. The remaining 51 percent of this line is within the Forest-Tundra and crosses increasing amounts of mature river bank spruce forests and tall shrub communities.

The Richards Island Supply Line, 143 miles in length, would lie 51 percent in low shrub-heath tundra requiring clearing only in mature river bank spruce forest at one major crossing of the Mackenzie River, at about Milepost 20, and at a few minor drainages. In the remaining 49 percent of its length, within the Forest-Tundra there is little change in the nature of the vegetation excepting an increase in spruce and mixedwoods near its terminus at the Travaillant Lake Junction.

The dominant feature of the vegetation of the pipeline route through both the Forest-Tundra and Boreal Forest in the Territories is spruce forest; primarily black spruce with sphagnum moss ground cover in the predominantly low wet terrain and with lichen ground cover on upland sites where white spruce is often intermixed. The wet lowlands of muskeg have only scattered small black spruce or lack trees entirely. Bogs and fens are scattered throughout. Organic terrain prevails along the planned alignment, peat thickness being greatest in bogs, fens, and muskeg and least on upland sites.

The total alteration of vegetation north of 60° N. latitude by right-of-way preparation would include the following acreages:

Table 3.1.2.6-2 Acreage of vegetation types along the proposed route, Travaillant Lake Junction to the 60° N latitude

Community Type	Forest-Tundra		Boreal Forest		Total	
	Acres	%	Acres	%	Acres	%
Bogs	0	0	3,000	0.06	3,000	0.04
Fens	82,200	4.10	314,300	6.48	396,500	5.50
Pioneer Riparian	23,300	1.16	17,400	0.36	40,700	0.56
Steep Slope	75,600	3.76	90,800	1.87	166,400	2.31
Mature Riparian	20,400	1.00	57,200	1.18	77,600	1.08
Recent Burns	508,000	25.30	75,700	1.56	583,700	8.09
Hardwoods	2,200	0.11	87,200	1.80	89,400	1.24
Mixedwoods	148,000	7.37	1,136,000	23.41	1,284,000	17.80
Mature Forest-Tundra	1,150,000	57.20	3,071,000	63.28	4,571,000	63.38
Total	2,009,700	100.00	4,852,600	100.00	7,212,300	100.00

Acreages and percentages include only areas having vegetation and exclude corridor areas of exposed rock and water bodies.
Hernandez (1974)

Herbaceous Coastal Tundra	2,899
Low Shrub-Heath Tundra	1,426
Forest-Tundra	8,564
Boreal Forest	9,772
TOTAL	22,661

The right-of-way would be machine cleared, or hand cleared in permafrost areas especially sensitive to disturbance of the peat moss layer and secondarily to the thermal balance of soils. The benefits of hand clearing, in contrast with construction sites for ancillary facilities, would probably be lost due to other unavoidable disturbances to follow, such as pipeline ditching, pipe-laying, and spoil pile clean up.

The 120-foot-wide right-of-way would be roughly divided into three parts; one-third for wheeled vehicle transport, one-third on the center line as a working lane for heavy machinery engaged in trenching, pipe-laying, welding, and related activities, and the remaining third would include an 8-foot ditch and spoil pile. The transportation lane would be a processed snow, ice-capped snow, or ice road, depending on locality and snow availability. In the Herbaceous Coastal Tundra and at crossings of bogs, fens, peat plateaus and muskeg in the Forest-Tundra and Boreal Forest, burial of the pipe with spoil materials from the trench excavation will frequently result in a surface of nutrient-poor peat. This organic layer or mixture will also be subject to extreme desiccation during the subsequent warm season and revegetation processes will be impeded.

Peat lands cover about 35 percent of areas traversed for about 40 miles of the Richards Island Supply Line; the entire area between Travaillant Lake and the Peel River; from Hare Indian River to Chick Lake; and most of the area from Willowlake River to the 60° N. latitude. Throughout these vast areas of organic and often ice-rich terrain, preservation of the ground cover vegetation and integrity of the moss-peat layer is essential to prevent terrain degradation. The construction impact will be major on the pipeline ditch one-third of the right-of-way and potentially major, and most probably moderate, on the work and transportation lanes.

Establishment and growth of plants on disturbed sites that are otherwise comparable are slower processes in tundra than in forested areas. Vegetation recovery in some tundra communities, especially cottongrass tussock and shrub-heath types, can be accelerated by reserving sod and replacing it at the surface. The Applicant has proposed stripping sod and placing it on the ditch line for such use. This might be difficult due to the fact the materials would be frozen during the winter construction period, the surface mat would be broken into small pieces, and the plant parts might not survive the mechanical damage and exposure.

The impact of the failure of these revegetation procedures would be continued, moderate to minor surface erosion on the right-of-way and a long-lasting visual scar which would be especially apparent on the treeless tundra. Further impacts along the right-of-way are treated in the following discussions.

Winter Roads--Snow and ice roads are planned for all areas for which permanent gravel roads are neither existent nor planned; this includes all the continuous and discontinuous permafrost zones north of 65° N latitude and intermittently south of 65° N. latitude wherever specific site investigations prove them necessary. Snow and ice roads afford a means of protecting the ground surface, the plant root zone, and the integrity of permafrost. They would be used for transportation between camps and construction sites, stockpiles, wharves, and borrow pits, and along the right-of-way. One-third of the right-of-way would be a snow-ice road and another third similarly constructed would serve as a work pad for pipeline construction. In the full construction time for the area north of 60° N. latitude approximately 185 miles of snow and ice temporary winter roads would be used in addition to similar pads on the right-of-way. Winter roads (Table 3.1.2.6-3) would affect at least 287 acres of Herbaceous Coastal Tundra, 56 acres of Low Shrub-Heath Tundra, 668 acres of Forest Tundra, and 400 acres of Boreal Forest.

The effectiveness of roads of compacted snow or ice is inadequately known with respect to protecting terrain and vegetation, especially on slopes, although some tests have been accomplished. Availability of snow in needed quantities would be a serious problem in many places, especially on the Arctic Coastal Plain and foothills. Snow and (or) water might have to be hauled for long distances with the risk of further impact on the environment. Such impacts would include damage to woody vegetation by cross-country or winter trail traffic; excessive draw-down of limited residual water in deeply frozen lakes and consequent loss of over-wintering fish; and increased heat loss and greater depth of freezing on lakes from which insulating snow might be removed.

Load and traffic tests on snow and ice roads on level ground at Norman Wells had the following results: live plant cover, mostly of resprouting shrubs, was 10 percent on the road site compared to 45 percent on control sites; thaw depth was 65 percent greater than on the control site; and compaction had increased peat density about 25 percent, but the mat was intact. These tests which are generally applicable to the Boreal Forest and Forest-Tundra indicate moderate to minor impact on vegetation on properly constructed and properly used winter roads on level ground. Any deviation in correct practices with such roads either on or off the right-of-way would result in major destruction of vegetation and compaction or destruction of the moss-peat mat and thermal degradation of ice-rich soils.

In 1974 a snow-ice road was constructed at Inuvik, N.W.T., that was stated (Northern Engineering Services Company Ltd., 1974a) to combine all of the topographic challenges expected of snow roads during pipeline construction, with the exception of river crossings and wind-swept tundra. The test road crossed 1) extremely hummocky terrain; 2) six creeks; 3) a hill with 16 percent maximum grade; 4) a sidehill with 11 percent slope; and 5) ice-rich soils. The test loop was 50 feet wide, 3,700 feet long and averaged 3 feet in thickness with a minimum thickness of 1 foot on the highest hummocks. Snowfall was light and it was necessary to borrow snow from a nearby lake and truck it to the test site. A short test section of road was constructed of snow manufactured by a compressed air operated snow gun. Snow was pulverized, leveled, and compacted into a snow pavement 10 inches thick. The hill section and a 90-degree curve were reinforced by ice capping.

Traffic tests consisted of 5,231 passes by a variety of equipment and vehicles, mostly in December 1973 and January 1974, and a smaller test in April. Maximum gross weight loads were 72,000 to 78,000 pounds, with ground pressure of 80 psi. Sidehill vehicle passes totalled 1,980 with 1,135 being at the maximum gross weight. The sidehill tests were inadequate, however, due to the location of the road between two curves, which forced vehicles to coast across the test section.

Table 3.1.2.6-3 Vegetation north of 60° N latitude altered by winter roads and stream crossings

	Acres (Estimated)			
	Stream Crossings			Winter Roads
	Single	Dual	Total	
Prudhoe Bay Supply Line	61	143	204	534
Herbaceous Coastal Tundra	46	-	46	287
Forest-Tundra	15	143	158	247
Richards Island Supply Line (Incl. Parsons Lake Laterial)	42	60	102	170
Low Shrub-Heath	34	60	94	56
Forest-Tundra	8	-	8	114
Mainline-Travaillant Lake to 60° N Latitude	81	76	157	707
Forest-Tundra	22	-	22	307
Boreal Forest	59	76	135	400
Total	184	279	473	1,411

Vegetation of the site, which lies within the Forest-Tundra, was open black spruce forest with a variable understory of dwarf willow and birch shrubs and heaths, with lichen and moss ground cover. Trees and larger birches were removed from the test area by hand clearing and low shrubs were compressed by equipment operating on the surface during preparation for snow road construction.

When traffic tests were terminated on May 6, 1974, due to warmer weather and the impossibility of repairing ruts with a grader, most of the snow was still in place with adequate protection to vegetation that would have permitted tracked vehicle and sled traffic. This type of traffic could possibly have continued use of the road for another 10 days. The road melted rapidly when temperatures consistently remained above 32° F. Low shrubs which had been compressed in the autumn showed little evidence of damage and there was no visible compaction of the moss-peat layer and only minor mechanical abrasions to the surface.

Investigation of the test site vegetation in July 1974, however, (Northern Engineering Services Company Ltd., 1974b) showed that evergreen shrubs (Labrador tea, bog rosemary, and lingonberry) were most severely damaged, their ground cover being reduced by 75 percent. Ground cover reduction was 69 percent for deciduous shrubs (alder, willow, birch, and blueberry) and 67 percent for herbaceous species. Lichens and mosses were less affected, showing ground cover reduction of 43 and 25 percent, respectively.

Measurements of surface elevation, organic layer thickness, and active layer thickness showed no significant change compared to the control area of undisturbed vegetation in this first warm season following the test. With minor exceptions the moss-peat layer remained intact and the sub-surface parts of damaged shrubs would be expected to sprout and the vegetation to recover. These results are at considerable variance with the Norman Wells tests, previously mentioned, and suggest snow roads may be less damaging at the latitude of Inuvik than at Norman Wells. This appears to indicate that the hill and sidehill tests are not applicable farther south along the Mackenzie Valley and that further evaluation is necessary.

Experience with snow roads in tundra regions, with less traffic intensity than would exist in pipeline construction, demonstrated the road area originally in shrub-heath vegetation to be essentially reduced to bare peat and with thaw depth 50 percent deeper than in control areas. In wet sedge meadows and lake-edge communities live plant cover was 30 to 50 percent and thaw depth was little changed compared to control areas.

The effectiveness of these roads would depend in large measure on their construction on undisturbed surfaces without grading, which often would not be avoidable on the right-of-way, and on the rigorous enforcement of cutoff time for their use in the spring. Major damage would occur if traffic were permitted after thaw started and the road had lost its structural integrity. If the roads were properly built and maintained, the moss and peat layer should be preserved, and eventually, the vegetation should recover by natural processes, augmented on the right-of-way by revegetation with agronomic grasses.

Failure of winter roads could result in major damage to low shrub-heath and forest-tundra vegetation from Richards Island for 420 miles to Fort Norman which is the southern limit of their planned use. Permafrost conditions for 140 miles south to the vicinity of Wrigley may also require snow and ice roads, implying further potential damage. The Prudhoe Bay Supply Line is equally vulnerable to vegetation damage throughout its length of 297 miles. The first 145 miles of this segment, crossing Herbaceous

Coastal Tundra on foothill slopes with ice-rich soils, would probably be affected by snow roads to a greater degree than any other part of the proposed route. Misuse of snow roads would result in a major impact on vegetation and the moss-peat layer of all such road areas.

Drainage Disruptions--Normal drainage patterns would be changed by the numerous crossings of side-slope drainages of all sizes. The Applicant plans to use permeable granular fill in the pipeline trench in critical drainage areas to permit drainage across the trench line. Hernandez (1974) cites evidence that granular fill in some cases of this type became ice-choked after 3 years, lost its permeability, and impounded water.

In the operational phase the pipeline would be refrigerated and formation of an annulus of frozen materials around the pipeline would further impede drainage. On slope crossings interrupted drainage would result in upslope impoundment of water and drowning of vegetation. Downslope wetlands would be deprived of water with resultant changes of habitat for both plants and animals. Ponding of water further changes the heat balance and induces thaw which in ice-rich soils can result in thermokarst topography with additional ponds. Such disruptions change habitats for vegetation and result in a local shift to communities of lakes and wetlands at the expense of upland, better drained communities. Such changes represent only a minor impact on vegetation and a trade-off of one community type for another.

Drainage disruption induced by the refrigerated pipeline would have its greatest impact in the discontinuous permafrost zone. The proposed route generally avoids side slopes and the impact of drainage changes on plant communities would expectably be minor and locally site-specific. The largest amount of side slope crossings would occur on the 297 miles of the Prudhoe Bay Supply Line, both in its crossing of the foothills and the Arctic Coastal Plain and in its traverse between the Mackenzie Delta and the east flank of the Richardson Mountains.

The pipeline berm, with or without refrigeration, would be frozen into the permafrost and, unless the active layer materials remained permeable, would constitute a dam to surface drainage. This could result in ponding and secondary effects on vegetation as previously mentioned and also erosion across the pipeline as well as along the right-of-way. The onset of summer thaw and drainage is rapid and could be destructive of vegetation especially in the cottongrass tussock and low shrub-heath tundra of the slopes.

Stream Crossings--The proposed route would cross numerous rivers and creeks, including three major dual pipeline crossings of the Mackenzie River and one of the Peel River, large enough to support communities of mature riparian spruce. Considering major streams to be those with drainage areas of 300 square miles or larger, there would be 23 major streams affected north of 60° N. latitude, although from an engineering point of view only the previously named river crossings would be considered major.

Hernandez (1974) considered stream crossings on the average would destroy 1 acre of vegetation per crossing. In the absence of estimates from the Applicant this figure is applied here, recognizing some crossings might involve larger areas and some less. Table 3.1.2.6-3 summarizes the estimated acreages of vegetation that would be affected by stream crossings.

Four major river crossings have been proposed for dual pipeline construction (CAGPL, 1975b). The large areas required for pipe preparation, doubling of construction, and the additional right-of-way for pipeline connection between the two lines on both sides of the rivers, will commit large acreages of forest vegetation during construction and lesser amounts for the duration of the project. The Peel River crossing, and the Mackenzie River crossing near Arctic Red River are within the Forest-Tundra (Table 3.1.2.6-3) and the East Channel of the Mackenzie River crossing at Richards Island is in the Low Shrub-Heath Tundra. In each of these cases, due to the riparian distribution of forests, the major impact would be on the mature riverbank spruce communities. The Mackenzie River crossing east of Fort Simpson would affect good quality mixedwood forests and fens.

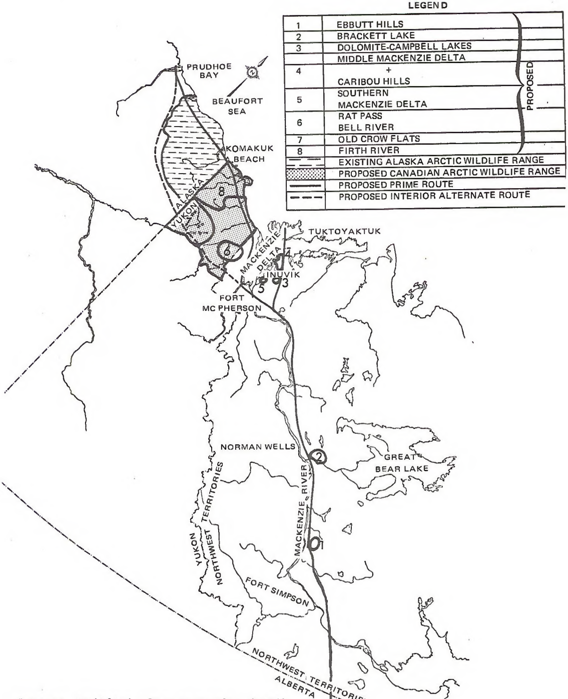
The following acreage figures are estimates based upon design drawings (CAGPL, 1975a) for construction areas and connecting pipeline right-of-way, respectively:

Peel River	60;12
Mackenzie River near Arctic Red River	36;35
East Channel of Mackenzie River at Richards Island	44;16
Mackenzie River at Fort Simpson	58;18

Ecological Reserves--The proposed pipeline in the Yukon Territory would cross the Canadian portion of the proposed International Arctic Wildlife Range (Figure 3.1.2.6-1) part of which already exists in adjacent Alaska as the Arctic National Wildlife Range. Hernandez (1974) also lists and indicates the importance of several ecological reserves proposed as part of Canada's participation in the IBP (International Biological Program). Among the eight proposed IBP sites only the Firth River Site and the proposed Arctic Wildlife Range, within which it lies, would be crossed by the proposed route. Vegetation would be affected by about 45 miles of right-of-way, one compressor station pad, one new and one existing airstrip, two communication towers, four borrow pits, and a wharf and stockpile on the Beaufort Sea coast. The permanent facilities and right-of-way would destroy or alter about 800 acres of wilderness-quality vegetation in the Herbaceous Coastal Tundra although the approximately 655 acres of right-of-way would recover through a combination of reseeding and natural succession of native plant communities. The impact would be major on wilderness values and moderate to minor on the natural ecosystem characteristics which the ecological reserves and wildlife range would preserve. The immediate coastal zone is no longer de facto wilderness and the proposed pipeline would be a further incursion on wilderness by shifting the area of human influences farther inland.

Endangered Plant Species--No rare species are known which might be threatened or endangered by the construction or operation of the pipeline or its ancillary facilities. While the possibility exists, it is improbable that the only extant representatives of a plant species population occur only on the right-of-way alignment or related areas that would be occupied by project components.

Introduction of Exotic Species--The Applicant (CAGPL, 1974b) has recognized that the use of commercial grasses for revegetation raises a problem of " ... legitimate concern regarding the ecological consequences of introducing new or exotic species into northern environments." Weedy species already exist in the North but their success depends upon availability of disturbed terrain and, while the project would increase such disturbed areas, there is little evidence that weedy species will invade undisturbed



Source: Modified after Hernandez (1974).

Figure 3.1.2.6-1 Location of proposed Canadian Arctic Wildlife Range and International Biological Program ecological reserves

vegetation. Hernandez (1974), who has studied the problem of agronomic species in tundra communities, states, "Reseeding with non-native species should not result in their invasion into undisturbed forest or tundra communities although they do produce viable seed." The impact of introduction of exotic species is considered to be insignificant north of 60° N. latitude.

Operations and Maintenance

Many environmental impacts of the construction phase of the proposed pipeline would continue throughout the life of the project. These include all components of the project such as roads, compressor stations and airstrips, among others, which commit land for the duration of the project. There are few strictly operational impacts, some of which were referred to previously (i.e., effects of refrigerated pipeline), but they may have importance as critical as anything considered in the construction category.

Warm Season Emergency Repairs

Warm season thaw of the frozen ground overlying permafrost renders terrain and its cover of vegetation vulnerable to damage by any type of vehicular traffic that creates ground pressure, either on or off the right-of-way. Emergency repairs of a major type, such as rupture of the pipeline, would entail movement of heavy equipment either along the right-of-way or across adjacent previously undisturbed terrain. Fires consequent to a pipeline break could involve movement of fire-fighting equipment long distances across country. The impact on vegetation and ground surface would be a major one, predictably as disturbing as that of any construction component. Spare parts and machinery, stockpiled at compressor stations, too heavy for air transport to the site of the emergency, would be forced to travel overland, perhaps on the right-of-way. Equipment mobilization from stockpiles 50 miles apart could result in 25 miles of overland travel and double this if the resources of two compressor stations were necessary. The right-of-way would be sensitive even to the effects of low ground pressure (LGP) vehicles and, depending on the timing, would probably be impossible to repair in the same season. The latter would apply especially to revegetation procedures and the disturbed areas would be exposed to continuing thaw and erosion.

Wet sedge meadows in the Tundra or fens in the Boreal Forest and Forest-Tundra are very susceptible to damage by track-laying machines or even by low ground pressure vehicles. Low shrub-heath communities are less damaged by these vehicles than are cottongrass tussock communities. All summer traffic would compress peat, reduce its insulation value and induce thaw. Stream crossing would carry the risk of bank disturbance, increased thaw, and accelerated erosion.

Throughout the area traversed by the proposed route north of 60° N. latitude, summer surface travel, either on or off the right-of-way, on wet peats and soils overlying ice-rich permafrost would have major impact on vegetation and terrain. The most seriously affected area would be the Herbaceous Coastal Tundra but the high incidence of fens, bogs and muskeg all along the route makes all off-road traffic a major impact of concern. The impact would be major wherever it occurred but the total overall impact cannot be estimated since the number, frequency and timing of the events cannot be predicted. The cumulative effects of rare to occasional events would at a minimum have large visual impact, especially on the tundra where scars are slow to repair.

Fire

Hernandez (1974) gives a very thorough and concise discussion of the ecological role of fire in northern plant communities, the occurrence and frequency of fires, and an excellent summary of fire history in the northern Boreal Forest and Forest-Tundra of both Canada and Alaska.

Fire is a significant, naturally occurring environmental influence in the North, and, in the absence of fire of human origin, would exhibit a natural pattern reflecting climatic aridity, combustibility of vegetation and the incidence of such natural fire-causing events as lightning strikes. Hernandez presents data for fires in the Mackenzie Valley for the period 1962 to 1971. Of 482 fires reported, 25 percent were caused by man, 43 percent resulted from natural causes, and 31 percent were of unknown origin. These fires (Table 3.1.2.6-4) varied greatly in size, from less than 1 to 249,000 acres.

Site moisture conditions and the amount of consumable plant biomass determine the extent of fires, hence tundra fires are less frequent and smaller than in the Boreal Forest and Forest-Tundra. Fens, bogs, and riparian communities seldom burn (Table 3.1.2.6-5).

Fire is such an integral part of the Boreal Forest and Forest-Tundra and has so many effects which are necessary or beneficial to the maintenance of the mosaic of characteristic plant and animal communities that the impact of the pipeline project could be positive in maintaining the natural balance of plant communities and wildlife habitat.

The large numbers of people who would be engaged in construction, as well as the fewer numbers involved in operations and maintenance, could increase the incidence of fire through careless practices. Construction in the winter season diminishes the prospect of fire and during the years of operation of the pipeline the improved surveillance and fire-fighting capability could reduce the number and extent of fires. Hernandez (1974) suggests, "the number of fires may increase as a result of the proposed project ... recent history (20 years) indicates that the total area burned should not increase." In permafrost areas fighting fires with off-road machinery may induce more undesirable changes to both vegetation and terrain than fire would, as previously discussed.

In calling for a fire-management program for the North, "... which recognizes the natural role of fire," Hernandez (1974) makes the significant recommendation, "With regards to the proposed pipeline, fires started by the project should be stopped. Natural distant fires which do not threaten the integrity of pipeline facilities, human settlements, or merchantable timber should not be fought."

Impact of Atmospheric Pollution on Vegetation

Atmospheric pollution could be at least a local problem at points all along the proposed pipeline route. Combustion products in the exhaust of the large numbers of construction machines that would be used and turbine engines at compressor stations, as well as noxious gases that would be emitted in gas and oil gathering fields and cleaning sites, could have toxic effects on vegetation.

Some plants are highly sensitive to sulphur oxides, certain lichens being so sensitive to the effects of sulphur dioxide that they have been used for many years as indicators of air pollution. The so-called "reindeer lichens," species of the lichen genus _Cladonia_, are important components of

Table 3.1.2.6-4 Frequency distribution of fires in the District of Mackenzie, N.W.T., and Yukon Territory north of 67° N latitude by size class during 1962-71

Size Class (acres)	Number of Fires Reported	Proportion of total Number (%)	Area Burned (acres)	Proportion of Total Area Burned %
0-1/4	136	28.2	14	0.00054
1/4-25	156	32.4	1,970	0.076
26-100	43	8.9	2,710	0.10
101-500	35	7.3	10,500	0.40
501-2500	46	9.5	69,000	2.6
2501-10,000	33	6.8	202,000	7.8
10,000-50,000	22	4.6	660,000	25.4
50,000-150,000	7	1.5	700,000	27.0
> 150,000	4	0.8	960,000	37.0
Total	482		2,606,000	

1/Product of mid-point of range x number of fires for each size class except for the two largest size classes where actual size of fires was used. (after Hernandez, 1974)

Table 3.1.2.6-5 Fire susceptibility for regions along the proposed route

Region	Rating [1/]	Characteristics Contributing to Rating
1. Coastal	1	Low biomass; moist to wet communities; fires rare, small
2. Interior	3	Mixture of forested (high biomass) and tundra (low biomass) communities; dry, moist and wet habitats; fires common
3. Delta		
(a) Delta proper	2	Forested communities; extensive river channels and lakes; fires rare
(b) Uplands	3	Low shrub tundra in the north scattered trees in the south (low to moderate biomass) some wet communities; fires common
4. North Mackenzie	5	Forest communities (high biomass); some wetlands; fires abundant
5. South Mackenzie		
(a) Norman Wells to Fort Simpson	5	Forest communities (high biomass); some wetlands; fires abundant
(b) Fort Simpson to Alberta	4	Forest communities; wetlands very common; fires common

(Source: Hernandez, 1974)

[1/] 1 Low potential for fire.
5 High potential for fire.

many communities and a significant food resource for animals, especially in the winter range of caribou. They are among the most sensitive lichens and long exposure to sulphur dioxide in concentration of 0.05 part per million (ppm) is damaging (Hernandez, 1974).

Turbine exhaust at compressor stations would include about 1 ppm of sulphur dioxide. Wind patterns and other meteorological conditions, especially temperature inversions, as well as topographic position of the individual station, would influence the magnitude of the effect. Based on stability Class F (inversions) it is calculated that the maximum ground concentration would be 0.00016 ppm. This agrees with the Applicant's value of 0.0002 ppm (CAGPL, 1974b). We conclude that no long-term effect on lichens will occur. Long-term cumulative effects of continuing exposure at low sulphur dioxide concentrations could have effects not now predictable (Hernandez, 1974).

Maximum exhaust gases of compressor turbines also would include oxides of nitrogen (about 130 ppm), carbon monoxide (10 ppm) and unburned hydrocarbons (5 ppm) which might have detrimental effects.

The Applicant (CAGPL, 1974b) states that calculated concentrations of nitrogen oxides are "... below level known to affect plants" and "... maximum concentrations of sulphur dioxide at ground level from compressor stations will be 0.0002 ppm" which "... should not affect lichens in any region in the North." This judgment is considered as probably valid but the impact of all such gases on vegetation requires further evaluation.

Wilderness Quality of Vegetation

Vegetation is an important element in the quality of wilderness. Direct losses by disturbance to vegetation per se may be of less significance than the secondary impact on ecosystems still remaining in their natural state. Large regions of the proposed pipeline route which would be transected are wilderness or quasi-wilderness and some, as the Tundra of the Yukon Coastal Plain, are of limited extent in Canada. Past human influences and highways planned or in various states of construction, such as the Dempster and Mackenzie Valley Highways, would have the major impact modifying remaining wilderness and accelerating human access to it. The cumulative impact of pipeline, highways, other engineering projects, and predictably large numbers of people who would follow, would have a major negative impact on the desirable attributes of wilderness land in its natural state without evidence of human influence. Along the specific alignment of the proposed routes the effect would be another increment of environmental change among a long history of changes.

Abandonment

With respect to the ultimate termination of the need for the proposed pipeline, the following is quoted from the Application (CAGPL, 1974b):

> "Governmental guidelines indicate a desire that the Applicant comment upon the steps to be taken upon abandonment of a pipeline. This is difficult to do realistically at this time, however, both because the conditions at that time cannot be known, but even more importantly, because that time will be so far distant. In light of the huge potential reserves of gas in the Canadian and Alaskan Arctic, it is certain that the Applicant's pipeline, once installed, will be operative for many decades. The gas reserves should last that long, and the

physical life of the pipeline, especially given modern construction and maintenance methods, should be longer. Already, one transmission line in Alberta has been in service for over 60 years. It is important to remember that natural gas is not only an energy source, but also a vital petrochemical building block.

"When abandonment becomes an issue decades from now, there are a variety of possible alternatives. For example:

"The pipe in the ground could be left in place. Succession of vegetative growth would continue on the right-of-way and eventually even the relatively minor visual evidence of the pipeline would disappear. The line would be in stable surrounding soil and would remain "frozen in" in permafrost soil.

"Surface facilities which were not found to be desirable for continued human use would be removed and salvaged. The remaining sites would be restored and returned to nature or turned to other human uses. (An example is that communication facilities could be put to other uses. However, they too could be removed if newer technology had become available and made them obsolete by that time.)"

In view of these uncertainties there is no means of assessing the probable impact of abandonment. Over the full length of the right-of-way the surface would be vegetation-covered at time of abandonment or would become so in a few decades, excepting the tundra vegetation types which would require longer periods of time. Abandonment of the pipeline would leave the terrain undisturbed whereas removal of the pipe would be highly destructive of vegetation and terrain.

Removal of structures and abandonment of gravel pads would present surfaces which would require very long time periods for vegetation recovery, especially in the tundra. The native plant communities would bear the scars of abandonment probably for several human generations.

The Provinces (South of 60° N. Latitude)

Impact on vegetation would generally decrease from north to south, largely in direct relationship to the gradual disappearance of permafrost and the terrain instability that can accompany it. The first 155 miles of the route south from the northern Alberta border lies within the discontinuous permafrost zone. Decreasing amounts of sporadic permafrost occur much farther south as island-like outliers or pockets of frozen materials in low, wet terrain of bogs and muskeg. Where such islands of permafrost are unpredictably encountered, disruption to the vegetation cover and overlying peat would result in thaw, subsidence and erosion, and consequent changes in habitats, as described for areas north of 60° N. latitude.

Southward across the provinces where the environment is more conducive to conventional pipeline construction methods, there is no necessity for restriction of construction to the winter season. Summer construction, increased availability of road networks, no requirement for snow and ice roads, and decreasing requirement for thick gravel construction pads all combine to lessen the potential impact the project would have on vegetation and terrain. Existing natural-gas pipelines parallel the proposed route for all but approximately 150 miles of its 1021-mile length in Alberta and for its total of 106 miles in British Columbia. There is a large background of pipe-laying experience demonstrating protection of vegetation and abiotic components of the environment is a minor problem off the right-of-way and that the right-of-way can be restored to agricultural and grazing use and all other normal functions, excepting the development of tree and tall shrub types of vegetation.

Impact of the proposed project will be considered for three pipeline segments, the Main Line from the Alberta border at the 60° N. latitude to Caroline Junction, the Kingsgate Delivery Line and the Monchy Delivery Line. The greatest impact would result from construction in the Provinces and there are no predicted additional effects on vegetation that are unique to the operational phase. No atmospheric pollution effects on vegetation are predicted. Fire effects in areas of summer construction would be a minor factor in both construction and operation as would off right-of-way disturbances in meeting emergency situations, including firefighting, over all but the muskeg terrain of northwestern Alberta.

Alberta Border (60° N. Latitude) to Caroline Junction

This segment of 48-inch pipeline 610 miles in length would lie within Boreal Forest communities (Table 2.1.2.6-1) for about 95 percent of its traverse. In the Peace River region it would cross about 30 miles of Aspen Parkland which is now more than 50 percent under cultivation. South of the Athabasca River on the approach to Caroline Junction scattered cropland occurs through a distance of about 150 miles of mixed aspen grove and spruce forests although cultivated land everywhere occupies less than 50 percent of the area (Govt. of Alberta, 1969). Excepting cultivated areas, the entire proposed route crosses lands classified as wildlands and is all occupied by coniferous and hardwood forests or their mixtures. For the first 50 miles in Alberta muskeg with scattered black spruce predominates. Muskeg is a prominent feature for about 50 percent of the route, decreasing in areal coverage from about 70 percent in the north to 25 percent or less to the south.

The impacts discussed for the route north of 60° N. latitude apply in some degree in this segment. Land would be taken out of use for other purposes, for the most part, for the duration of the pipeline, for the 120-foot wide right-of-way and the acreage occupied by related, permanent facilities (Table 3.1.2.6-6). The total area of vegetation that would be destroyed or disrupted is 10,167 acres of which 1,225 would be occupied for the duration of the project and 8,942 acres would be taken by right-of-way on which vegetation would recover, excepting trees which would not be permitted to develop.

Pipeline Right-of-Way

Clearing and other right-of-way preparations would be accomplished in the winter season, by the same methods described for the Territories. Winter construction would be used except for a short segment approaching Caroline Junction which, as in the case of both delivery lines south of Caroline, would be constructed in the summer season. The impact on the right-of-way would be the temporary removal of 8,942 acres of vegetation and removal of forest production for the life of the project. Degradation of sporadic permafrost in the predominantly muskeg terrain of about 150 miles of the route in northern Alberta could create problems of erosion control but the impact on vegetation is considered to be minor or insignificant.

Table 3.1.2.6-6 Areas of vegetation formations affected by the proposed route in Alberta, Saskatchewan, and British Columbia

	Pipeline Right-of-way	Compressor Stations	Communication Towers	Airstrips	Perm. Project Roads	Wharves, Stockpiles, Misc. Pads	Borrow Pits	Total
Mainline-60° N Latitude to Caroline Junction	8,942	552	83	350	32	8	200	10,167
Boreal Forest	7,843	523	72	350	32	8	200	9,028
Aspen Parkland	1,099	29	11	-	-	-	-	1,139
Monchy Delivery Line	5,739	204	44	-	-	-	-	5,987
Aspen Parkland	873	-	11	-	-	-	-	884
Grassland	4,866	204	33	-	-	-	-	5,103
Kingsgate Delivery Line	4,089	117	39	-	-	-	-	4,245
Aspen Parkland	1,252	30	6	-	-	-	-	1,288
Grassland	945	29	11	-	-	-	-	985
Subalpine Forest	1,019	29	5	-	-	-	-	1,053
Ponderosa Parkland	291	-	6	-	-	-	-	297
Interior Wet Belt Forest	582	29	11	-	-	-	-	622
Total	18,770	873	166	350	32	8	200	20,399

Winter Roads

There would be no use of snow and ice roads at the latitude of this segment. Vehicular traffic and machinery would utilize frozen ground lanes on and off the right-of-way wherever existing roads and 32 miles of permanent project roads would not serve. Winter roads or trails would be prepared by vegetation clearing and by early snow removal to allow frost penetration sufficient to support traffic. Impact on vegetation would be minimal other than on the right-of-way.

Drainage Disruption

The effects of the refrigerated pipeline would be relatively minor in this part of the route. Temperature would be maintained below 32° F for the first 4 years of operation only in a segment extending 37 miles south from the N.W.T.-Alberta border (CAGPLc, 1974, 17.2.1, p. 2). The formation of a frost bulb around the pipe could temporarily cause ponding upslope and deprive downslope vegetation of its water supply, as previously described. The pipeline generally would avoid sideslopes and follow lowlands across the few miles of northern Alberta where freezing temperatures of the pipeline could be a factor. The potential impact on any vegetation type is considered to be insignificant.

Emergency Repairs

Emergency repairs necessitating major movement of heavy equipment along the right-of-way or across country in the summer would be a minor problem in this section of the route although it is a matter for some concern in the area of sporadic permafrost, which extends to the region of the Athabasca River, and in all wetlands of muskeg terrain. In the southern portions, the right-of-way would more readily withstand traffic and off right-of-way traffic would not be indicated. Further, the road networks enable easier access to emergency sites. Since the frequency or place of occurrence of emergency events cannot be foretold it is not possible to evaluate the total impact.

Fire

As discussed for the Forest-Tundra and Boreal Forest north of 60° N. latitude, fire is an annual, warm season threat throughtout the Boreal Forest of Alberta and the adjacent Provinces. Upland vegetation of spruce, poplar, jack pine, lodgepole pine, aspen and birch are subject to recurrent fires and the widespread dominance of aspen is a common consequence of burning of coniferous and mixedwood forests. As north of 60° N. latitude, the successional stages of vegetation developing toward coniferous forest represent an equilibrium state important to maintenance of wildlife habitat.

The possible impact of an increase in fires of human origin as a result of pipeline activities is limited in importance. Although most of the right-of-way construction would be in winter other facilities would be built in summer. The potential for starting fires would be greater here during the construction phase than it would be in the Territories. Southward along the route the increasing density of human population and the works of man, including the facilities of the proposed pipeline, suggests that fires would be reported early and fought vigorously. Overall, the impact of fire on vegetation would be minor and, as stated before, would be beneficial except in areas of productive forests of merchantable quality.

Caroline Junction to Kingsgate

The Kingsgate Delivery Line, 281 miles of 42-inch pipeline, between Caroline Junction, Alberta and Kingsgate, British Columbia (Table 2.1.2.6-1), would occupy 4,245 acres of land, 96 percent of it by right-of-way. Four planned or future compressor stations, six communication towers and one stockpile site are the only facilities. The potential impact on vegetation is essentially reduced to the losses resulting from right-of-way clearing and the withdrawal of this area from forest production for the duration of the project. Fifty-four percent of the route would lie within former Prairie Grassland and Aspen Parkland which now are more than 50 percent under cultivation (Govt. of Alberta, 1969). Less than 2,000 acres of the combined Subalpine, Ponderosa Parkland and Interior Wet Belt Forests would be directly affected by right-of-way and other facilities.

Summer construction carries some threat of forest fire of human origin as would pipeline accidents during the years of pipeline operation. Especially the subalpine forests, lying in the rainshadow of the east front of the Rocky Mountains, would be vulnerable to fire. Late summer and autumn fires are common and have an important bearing on the display of such fire-related vegetation as hardwood-pine stands and mixedwoods.

Caroline Junction to Monchy

The Monchy Delivery Line for its entire 394-mile traverse across Alberta and Saskatchewan would lie within the Prairie Grassland and the Aspen Parkland which borders it. More than 50 percent of the area of these original vegetation types is now cropland or pasture (Govt. of Alberta, 1969; Richards and Fung, 1969).

The total land use in the Aspen Parkland (Table 3.1.2.6-6) would be the area of the right-of-way, 884 acres. In the Prairie, where only remnants of grassland remain, the right-of-way would take 4,866 acres and other facilities 237 acres.

Impact of the project on vegetation would be the same as for the Alberta portion of the Kingsgate Delivery Line. Vegetation would be cleared from the right-of-way and the small areas of ancillary facilities. Fire originating from project activities would be of little significance to natural vegetation in this agricultural and urbanized area.

Impact on Forest Resources

The proposed route would cross four areas in Alberta which are classified as productive forest land. From north to south these include forests which are the basis for a thriving lumbering industry:

1) The Hay River region in northwestern Alberta, including the industry based on spruce timber in the Zama Lakes and High Level areas. This region is characterized by productive forests of deciduous hardwoods and mixedwoods. These types of forests continue southward to the agricultural area of the Peace River country.

2) The Fox Creek area, south and southwest of Lesser Slave Lake, where the lumbering industry is based mostly on the harvesting of pine.

3) The Edson-Whitecourt-Carrot Creek area, about 100 miles west of Edmonton, where the industry is based on spruce, pine and mixedwoods.

4) Rocky Mountain House, about 20 miles north of Caroline, where merchantable stands of aspen occur to the north between the Pembina and North Saskatchewan Rivers.

The impact of the pipeline would be the clearing of a 120-foot-wide right-of-way through about 290 miles of the best quality forest lands. This would amount to removal of about 4,200 acres of trees from land designated as productive forests by the Alberta Department of Lands and Forests.

In British Columbia two logging areas would be affected along about 45 miles of route (CAGPL, 1974c). One of the areas includes the Michel Creek, Leach Creek and Flathead River valleys and the second is the Teepee Creek valley. The latter is the only area traversed which has unharvested, mature pine forests. The pipeline would remove about 655 acres of forest land from production for the duration of the project.

There are no forest areas in the part of Saskatchewan that would be traversed by the Monchy Delivery Line.

Conclusions on Impact of the Proposed Route

The temporary impact of locating a gas pipeline along the proposed route would be major for the total pipeline right-of-way but only moderate in the years of the project operational phase. Of the total 43,060 acres of vegetation that would be initially destroyed or significantly altered by the right-of-way, borrow pits and permanent facilities, about 80 percent would be taken by right-of-way (Table 3.1.2.6-7). The more enduring impact would be primarily on visual scarring of treeless areas and removal of timber production in forested areas. About 26 percent of the right-of-way would fall within Aspen Parkland and Grassland regions where agriculture is widely practiced and impact on natural vegetation would be minor.

Major impact would result from borrow pits and permanent project roads and facilities. Vegetation losses to these functions would total 7,928 acres, about 18 percent of the total acreage, and would last for the duration of the project. The impact of these project functions and right-of-way effects, in terms of the total vegetation resources of the regions traversed, would be minor.

North of 60° N. latitude in permafrost areas major impacts would result from improper use of snow and ice roads, destruction of the thermal insulation value of the moss-peat layer, disruptions to drainage, and warm season right-of-way or cross-country operation of vehicles and machinery. With reference to the total vegetation resource these impacts would be moderate, except in the Herbaceous Coastal Tundra where the resource is limited and restorative processes are slow.

Pollution effects of toxic gases from machinery and compressor station turbines would have no effect, or only minor effects, on vegetation over most of the route.

Fire is a natural, annual threat over the entire pipeline route although of minor significance in tundra types of vegetation and especially in the Herbaceous Coastal Tundra. Project-induced fires, either from human carelessness or pipeline accidents, would involve only minor impact on vegetation except in the areas of productive forests of merchantable timber. Fire is an important natural influence in maintaining the balance of Boreal Forest vegetation and ecosystems and the threat of pipeline-related fires would be of minor significance.

Table 3.1.2.6-7 Major plant communities (acres) that would be initially committed to the proposed route

Vegetation Region (or Ecosystem)	Right-of-way	Permanent Facilities	Perm. Project Roads	Borrow Pits	Total (acres)
Herbaceous Coastal Tundra	2,152	529	35	183	2,899
Low Shrub-Heath	1,078	215	22	111	1,779
Forest-Tundra	5,892	1,903	300	469	8,564
Boreal Forest	15,083	2,393	654	670	18,800
Aspen Parkland	3,224	87	0	0	3,311
Prairie Grassland	5,811	277	0	0	6,088
Subalpine Forest	1,019	34	0	0	1,053
Ponderosa Parkland	291	6	0	0	297
Interior Wet Belt Forest	582	40	0	0	622
Total (acres)	35,132	5,484	1,011	1,433	43,060

Vegetation of the proposed Firth River/IBP (International Biological Program) Site and the Canadian Arctic Wildlife Range would be moderately affected by the project in terms of the direct impact. In terms of the objective of the proposed ecological reserves, the complete protection of the wilderness ecosystems, the impact on the 45-mile segment traversed would be major.

In consideration of all project components and their effects on all vegetation over the full 2,435 miles of the pipeline system in Canada the total impact of the proposed project on vegetation would be minor in the long term. The greatest impact, which would be irrevocable, would be a further intrusion on the wilderness-quality vegetation, especially the Herbaceous Coastal Tundra.

3.1.2.7 Wildlife

Fishery Resources

Construction of a gas pipeline along the proposed route would cause some primary damage to the fishery resources, but the greatest long-term threat to aquatic organisms along the northern portion of the route could be a gradual degradation of water quality and over-exploitation of the fishery resource due to increased human activity.

Impact of Increased Turbidity and Siltation

Construction Phase

Construction during the winter months could cause increased turbidity during the following period of spring thaw and run-off. Ditching, pipe laying, backfilling, approach preparation, and associated activities in or near streams would increase turbidity and siltation in streams. Clearing of right-of-way plus construction and use of temporary and permanent roads could increase turbidity and siltation also.

All streams in the vicinity of the proposed pipeline have varying amounts of natural turbidity and siltation. Those streams with the least amounts would be most affected by increased turbidity levels due to construction. Streams with extreme clarity and low siltation such as those streams flowing from large lakes (Great Bear River, for example) would be affected adversely if periods of high turbidity and siltation levels remained beyond a year. In most instances high turbidity and siltation would subside within a few months following construction activities. Streams are normally most turbid during and immediately following the period of ice breakup. Increased suspended sediments during the summer could inhibit photosynthesis by the plant community and limit production of fish and other aquatic organisms. Increased turbidity during the winter could adversely affect overwintering fish and the eggs of fall spawners.

Increased turbidity reduces light penetration which in turn decreases primary productivity, thus adversely affecting the entire food chain. Increased siltation smothers benthic organisms, fish eggs and embryos, and mussels. Most effects of high turbidity are subtle, but nonetheless significant. In addition to decreased productivity resulting in slow growth, fish become stressed and less resistant to disease.

Increased siltation adversely affects the early life stages of many fishes. Eggs and larvae of salmonids in particular develop within beds of gravels and require well-oxygenated, flowing water for the developing larvae. Silt fills the gravel interstices, thus reducing the supply of oxygen and blocks the emergence of the fry. Survival after emergence is decreased also due to the loss of escape cover between stones and due to reduction in available invertebrate food organisms.

The highest increases in turbidity and siltation would occur downstream from stream crossings. The route of the proposed pipeline crosses an unnamed waterway near Milepost 199, the Firth, Spring, Crow and Babbage Rivers, Deep Creek, Walking River, Rapid Creek, and Fish River in the Beaufort Sea drainage. In the Mackenzie River drainage the proposed route crosses at least 45 waterways important to the fishery resource of the area (Table 3.1.2.7-1).

Since several tributaries of the Mackenzie drainage system thaw in succession, there would probably be a cumulative effect on the main stem of the river. Sediment loads could be expected to extend to a period of up to 1 month annually. The sediment load down river could be significant; however, the impact probably would not be severe as the Mackenzie River is not greatly utilized for spawning.

South of 60° N. latitude the proposed pipeline would cross the Hay, Chinchaga, Meikle, Hotchkiss, Notikewin, Whitemud, Peace, Smoky, Little Smoky, Athabasca, and McLeod Rivers. South of Caroline Junction the route crosses the North and South Saskatchewan, Bow, Oldman and Red Deer Rivers in the Saskatchewan River drainage, the Frenchman River in the Mississippi River drainage, and the Elk and Kootenay Rivers in the Columbia River drainage.

Increased siltation and turbidity would have an adverse effect on salmonid reproduction in the Elk and Kootenay Rivers. The rivers crossed on the east side of the continental divide and south of Caroline Junction do not have important salmonid spawning runs in their lower stretches where the pipeline would cross.

During and shortly after the actual ditching and backfilling across streams, turbidity and siltation would increase several fold. Suspended sediment in the La Biche River increased about 542 ppm during trenching. Mayfly and stonefly populations are particularly sensitive and their abundance would probably decrease greatly during and immediately following construction. Eggs and larvae of Arctic grayling undergoing development in gravel substrates at and downstream from the crossings would experience varying degrees of mortality. As spring flows diminished and silt deposition increased, adult fish would probably avoid sections of streams having high silt loads. If stabilization of stream banks and bottoms were successful following construction, turbidity and siltation should return to pre-construction levels in 1 or 2 years and aquatic populations would return to their former abundance. Continued erosion and siltation in streams in the Mackenzie River drainage north of 60° N. latitude could have adverse effects on the developing eggs and larvae of Arctic char, whitefish, and ciscoes. If banks and stream cuts were not stabilized, turbidity and siltation from increased erosion could be expected to continue and exceed pre-construction levels. Productivity of aquatic organisms would probably remain at a reduced level from pre-construction levels. Population structure would be modified. Sensitive species such as Arctic grayling and Arctic char would decrease and silt tolerant species such as suckers would increase in abundance.

A serious increase in turbidity and siltation could occur from erosion caused by right-of-way clearing, road construction, and fires that consume areas of terrestrial vegetation. Large quantities of suspended solids and siltation could come from construction of permanent roads, temporary roads,

Table 3.1.2.7-1 Waterways north of the 60° N latitude significant to the fish resource

	Activity in Relation to Stream Crossing			
Name	Spawning	Nursery	Over-wintering	Migration Route
Unnamed (Milepost 360-370)	upstream	upstream		yes
East Channel Mackenzie River				yes
Peel River	upstream	upstream	upstream(2)	yes
Frog Creek	downstream	downstream		
Unnamed (Milepost 445)		downstream		
Mackenzie River			upstream & downstream	
Thunder River	upstream	upstream		
Unnamed (Milepost 210)		downstream		
Unnamed (Milepost 230)		downstream		
Unnamed (Milepost 235)		downstream		
Treda River		upstream	upstream	
Loon River	downstream	downstream	upstream	
Hare Indian River	upstream	upstream		
Elliot Creek		upstream	upstream	
Oscar Creek	upstream	upstream		
Bosworth Creek		upstream		
Canyon Creek		upstream		
Francis Creek		upstream		
Christina Creek		upstream		
Prohibition Creek		upstream	upstream	
Vermillion Creek	upstream	upstream	downstream	

Table 3.1.2.7-1 (Continued)

	Spawning	Nursery	Over-wintering	Migration Route
Great Bear River	upstream	upstream		yes
Unnamed (Milepost 435)		downstream		
Unnamed (Milepost 445)		downstream		
Big Smith Creek		upstream		
Little Smith Creek		upstream (2)	upstream	
Unnamed (Milepost 470)		upstream		
Saline River		upstream		
Stees Creek			upstream	
Blackwater River		upstream (2)	downstream	
Unnamed (Milepost 525)			upstream	
Unnamed (Milepost 535)		upstream		
Ochre River	upstream	upstream		
Unnamed (Milepost 555)		upstream	upstream	
Smith Creek		upstream		
River Between Two Mountains	upstream	upstream		
Unnamed (Milepost 590)			upstream	
Willowlake River	upstream	upstream	upstream	
Mackenzie River			upstream & downstream	yes
Jean Marie Creek	upstream	upstream		
Trout River	upstream & downstream	upstream & downstream		yes
Kakisa River	downstream			

and winter trails (Table 1.1.2.3-4) along the Mackenzie River. Peak levels of turbidity and siltation would not be as great from these activities as from stream crossing operations. However, continued siltation would reduce primary and secondary production and could reduce intragravel water flow affecting the survival of fish eggs and larvae. Instances of extended erosion would more likely occur following construction activities in the permafrost area where revegetation is slow and erosion persists.

Operation and Maintenance Phase

Operation and maintenance of the proposed pipeline and related facilities would be expected to cause only a slight increase in turbidity and siltation. Probably the greatest area of concern would be maintenance and operation of permanent roads and of snow or temporary winter roads occurring along the route (Table 1.1.2.3-4). Especially acute would be erosion along roadbeds and pipeline right-of-way near river crossings (Table 1.1.2.3-2). Added turbidity and siltation would not be as acute south of 60° N. latitude because many of the streams are already turbid and the fish present, such as suckers, minnows, and yellow perch, are more tolerant of these conditions.

Impact of Stream Blockage

Arctic char and Arctic grayling migrate between the Beaufort Sea and the Malcolm, Babbage, Blow and Fish Rivers. Whitefish, inconnu, and cisco migrate from the Mackenzie Delta into the Beaufort Sea and also up the Mackenzie, Peel, Arctic Red and Great Bear Rivers. Arctic grayling, northern pike, walleye and longnose suckers move between the mainstem Mackenzie River and its upriver tributaries. Blockage of waterways would be detrimental to these species. If a stream should become blocked prior to time of spawning, spawning would not occur in affected sections and a year class would be lost in that particular stream.

Construction Phase

Nineteen wharves are scheduled for construction in the Yukon and Northwest Territories. Four of these are sited at Mileposts 360, 385, 430 (Peel River) and 460 on the Prudhoe Bay Supply Line. The remainder would be built along the Richards Island Supply Line and the Main Line along the Mackenzie River. Berms or barges would be used to make pipeline crossings on the Mackenzie and the Great Bear Rivers. These structures represent potential blockages to fish migrations.

Operation and Maintenance Phase

Two foreseeable potential barriers to fish movement are velocity barriers, particularly from culverts, and physical barriers from the pipeline causing formation of ice plugs. Culverts would be placed on access roads to about 13 staging areas in the Mackenzie River drainage and the 3 staging areas at Malcolm, Firth and Fish Rivers in the Beaufort Sea drainage.

The placement of the refrigerated pipeline under the surface of the stream bed might produce a frost bulb which would deflect subsurface waters to the surface where they would freeze and form ice dams which would persist after the spring break-up. Streams such as the Malcolm, Firth, Babbage and Fish Rivers in the Beaufort Sea drainage which have small volumes of water would be most susceptible to blockage by ice dams. Ice dams could prevent fish from making necessary migrations.

Impact of Reduced Oxygen Levels

The dissolved oxygen levels for selected streams in the Beaufort Sea drainage and Mackenzie River drainage north of 60° N. latitude are given in Tables 3.1.2.7-2 and -3 respectively. Those streams with less than 4.0 ppm dissolved oxygen would be the most critical. Most such streams occur in the Beaufort Sea drainage. In the winter, fish are concentrated at locations having sufficient dissolved-oxygen levels. Reduction of these levels by the addition of sewage, methanol, or fertilizers would be detrimental to oxygen-sensitive Arctic char, Arctic grayling, and stoneflies and mayflies especially in the small watercourses of the Beaufort Sea drainages.

Construction Phase

Sewage would be generated at camps located at the sites of major construction activities, large unloading sites, and the 3 compressor stations in the Beaufort Sea drainage, the approximately 25 compressor stations located along the Mackenzie River drainage north of 60° N. latitude and the 25 situated south of 60° N. latitude. Peak employment and presumedly peak sewage production would occur in the interval between the summers of construction years 2 and 4 when between 5,400 and 7,500 persons would be working (Figure 1.1.2.6-2).

Methanol, which the Applicant proposes to use to test for pipeline leaks in the permafrost zones prior to startup, could create an oxygen demand if large amounts were leaked into small bodies of water. If levels are kept under 10 mg/l as recommended by the Environment Protection Board, problems should be minimal.

The application of inorganic fertilizer containing nitrogen, phosphorus, and potassium to the right-of-way during the first spring following construction could be carried into waterways by runoff. The addition of fertilizer would encourage the growth of aquatic plants which could lower levels of dissolved oxygen. However, a "one-time" application should have little or no lasting effect.

Operation and Maintenance Phase

In the fifth operating year an estimated total of 390 persons would be stationed at Inuvik, Norman Wells, Fort Simpson, Peace River and Calgary (Table 1.1.2.7-1). Personnel involved in preventive maintenance and routine inspection would be moved to compressor stations for from one to several days at a time so the production of sewage and its potential for reducing dissolved-oxygen levels in waterways would be less than during the construction phase.

Impact of Spills of Fuel, Gas and Methanol

Construction Phase

Between Richards Island and 60° N. latitude, fuel would be stored at about Mileposts 20, 175, 220, 260, 290, 310, 375, 420, 490, 535, 580, 620, 645, 670, and 705. On the Prudhoe Bay Supply Line, fuel storage would occur at Komakuk and Shingle Point on the Beaufort Sea coast and at about

Table 3.1.2.7-2 Dissolved oxygen levels in selected waterways of the Beaufort Sea drainage during the winter of 1973

Waterways:	Dissolved Oxygen (ppm)
Rat River	1.6
Cache Creek Spring	0.5,4.0
Crow River Spring	2.6
(Big) Fish River	0.3
Unnamed Lake	3.4
Spring River Seep	3.0
Firth River	9.4
Fish Creek Spring	5.0
Unnamed Spring	6.2
Unnamed Lake (1)	16.0
Unnamed Lake (2)	11.6
Unnamed Lake (3)	11.6

(Data from Environment Protection Board)

Table 3.1.2.7-3 Dissolved oxygen levels in selected waterways of the Mackenzie River drainage during the winter of 1973

Waterways:	Dissolved Oxygen (ppm)
Mackenzie River	13.0
Willowlake River (2)	7.0
River Between Two Mountains	12.4
Blackwater River	12.0
Great Bear River	7.5
Hare Indian River	6.8
Travaillant River	13.4
East channel-Mackenzie River (2)	11.0
East channel-Mackenzie River (4)	12.0

(Data from Environment Protection Board)

Mileposts 365 and 385. Due to the high toxicity of fuels, spills could have a significant impact on fishes and aquatic insects. Methanol mixed in water (concentration 26 percent or less) would be used as a pipeline test medium in permafrost areas. According to McMahon and Cartier (in Environment Protection Board, 1974, Vol. IV, p. 229) neither the fry of Arctic grayling or Arctic char can tolerate exposure to more than 1 percent methanol for 24 hours. In a test at the same concentration and duration the eggs of these species were apparently damaged, and showed delayed development, and there was mortality of Arctic grayling during the hatching process.

Operation and Maintenance Phase

Natural gas would probably be the chief contaminant leaked during the operational phase. Pipeline gas would consist of more than 90 percent methane. Methane occurs naturally as swamp gas produced by anaerobic degradation of more complex organic substances. Toxicity of methane to fish is low, aerobic degradation is rapid, and much of leaking natural gas would dissipate into the atmosphere. In small waterways natural gas spills could deplete the oxygen and cause fish kills. The likelihood is not considered great, however.

Impact of Increased Water Usage

Construction Phase

North of 60° N. latitude large quantities of water would be used for winter roads, pipeline testing, and domestic use, in that order. The estimated usage of water, according to the Applicant, is given in Table 3.1.2.7-4. Throughout much of its length the pipeline would be near large streams having large winter flows which would serve to provide water without causing significant reduction in total discharge. Major streams entering the lower Mackenzie River from the east (Table 2.1.2.7-2) flow throughout the winter. However, none of the streams in the Malcolm, Firth, Spring, Crow, Babbage, Walking, Blow, and Fish River drainages in the Beaufort Sea region have a significant winter discharge. The tapping of lakes or subsurface sources of water in this region could reduce the fresh water supply of streams and lakes which serve as overwintering areas for species of Arctic grayling and Arctic char. A disruption of the water supply could destroy aquatic species in these areas. The extraction sites south of 60° N. latitude are not described by the Applicant. However, there should be no real problem in this area, because of sufficient flows during the winter.

Operation and Maintenance Phase

The use of water for pipeline testing and domestic use would be reduced from the construction phase, as there would be no testing and only water for about 390 personnel in the fifth operation year would be required.

Impact of Increased Human Utilization

Fish in the North grow more slowly, become sexually mature later, and have lower turnover rates than comparable populations to the south. These characteristics make them more susceptible to over-exploitation.

Table 3.1.2.7-4 Anticipated usage of water during pipeline construction

	WINTER 1976/77	SUMMER 1977	WINTER 1977/78	SUMMER 1978	WINTER 1978/79	SUMMER 1979	WINTER 1979/80
Water for construction camps, testing, snow and ice roads, etc. (in thousands of barrels; 1 barrel = 42 gallons)	300	500	13,500	7,500	12,000	500	8,000

Construction Phase

Construction work north of Caroline Junction would take place during winter while construction south of that point is scheduled for summer. If fishing occurs little impact is expected in the Beaufort Sea region and the upper Mackenzie River drainage, because construction is scheduled to take place during the winter when water courses are frozen and fishing would be difficult. Impact on the Saskatchewan, Missouri and Columbia River basins would take place during the summer but should be small as fish in these streams are conditioned to sport fishing and would be more difficult to exploit than fish in the Beaufort Sea and Mackenzie watersheds.

Operation and Maintenance Phase

In the fifth operating year about 390 people would be employed at Inuvik, Norman Wells, Fort Simpson, Peace River and Calgary (Table 1.1.2.7-1). These people, unlike the construction workers, would be allowed to fish subject to the rules of the territorial agencies north of 60° N. latitude and Provincial agencies south of 60° N. latitude. These workers would compete with the Natives for the salmonids, walleye, and northern pike found north of 60° N. latitude (Table 2.1.2.7-3). A secondary increase in the utilization of fishery resources would probably occur in the Mackenzie drainage and Beaufort Sea drainage from sportsmen attracted to the area by increased access provided by additional roads and the construction of 21 new airstrips and the improvement of existing airstrips at Fort Norman, Wrigley, and Fort Good Hope. The magnitude of the increase in fishing pressure from this source is unknown but probably would be considerable.

Mammals

In Canada the number of mammalian species of wildlife that would be affected to some extent directly or indirectly by the construction and operation of the proposed pipeline is 100 (Table 2.1.2.7-9). The overall impact to populations of abundant, widely distributed species would be less than those of declining, threatened, rare, or endangered species. Distribution of a species, whether year-around or seasonal with migrations or movements involved, is determined by habitat and by places where they can survive and reproduce. Although fluctuations of numbers in a species population is the rule rather than the exception, each block of vegetation-covered land supports a fauna; conceptually, this capacity to sustain the animal population is the carrying capacity. Herbivores are plant eaters. Predators are animal eaters, and are either those that eat meat (carnivores) or those that eat insects (insectivores).

Large Herbivores

Large herbivores are of considerable economic importance to man, providing food and clothing to local inhabitants and attracting sport hunters who contribute funds to the local economy and to the perpetuation of the resource.

Large herbivores tend to be limited more by the quantity and quality of the forage available to them in winter than in summer. Clearings for pipeline right-of-way, roads, airfields, compressor stations, borrow pits, and communication towers would destroy forage plants. Deep or crusted snow may restrict animals to areas where forage is exposed by wind, is tall enough to reach above the snow surface, or is otherwise accessible. Any reduction in quantity, quality or availability has a significant adverse impact on wintering species. Increased predation, starvation and subsequent reduction in productivity are consequences of loss or deterioration of winter habitat or range. If the proposed pipeline were built, accidents such as collisions with vehicles and falls into open pipeline trenches would cause the death of individual large herbivores, but the number would probably not be large.

Caribou

Caribou may be encountered along the proposed pipeline route throughout its range into northern Alberta. The greatest impact would be on the Porcupine herd in the coastal segment of the route. This herd has flourished because of the isolated and undeveloped state of its habitat, so any change would be adverse. Vulnerability of this herd to changes is of concern to Canada, to the United States, and to the Native and other people now living in the region.

The herd, named after the Porcupine River and numbering some 110,000 to 140,000 barren-ground caribou, is the largest group of animals along the proposed pipeline route. Feeding on lichens and grasses, the herd migrates through central and northern Yukon and adjacent parts of the Northwest Territories and Alaska, thereby constituting a joint Canadian and United States responsibility.

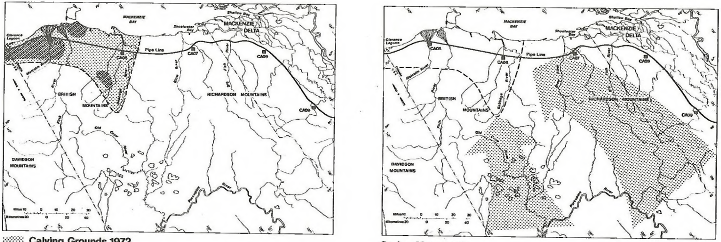
Generally the herd spends the summer in the northern Yukon (Figure 3.1.2.7-1) and adjacent Alaska, and in the fall the animals move south to the Peel River drainage basin where they overwinter. In spring, they move northwards to the Arctic coast, and calves are born from late May to mid-June. After calving the herd swings westward along the North Slope of the Yukon into northeast Alaska.

Surveys made during 1971 and 1972 showed that in these years most of the Porcupine caribou herd wintered in the central Yukon utilizing the entire Porcupine Plateau. During 1972-73, however, the winter distribution differed. The herd moved more to the west into Alaska in the area around Arctic Village.

Observations made by DeBock and Surrendi (1974) in 1973 and 1974 also showed appreciable variation in winter distribution and in spring movements, suggesting a general picture of marked year-to-year variability in migration pattern. Therefore, although pipeline development would avoid the more frequently used area of winter habitat, there is no guarantee that in particular years conflicts would not occur. In addition, it must be noted that a small but important part of the herd--normally numbering about 5,000 animals but increasing to 20,000 in 1972--overwinters on the eastern slopes of the Richardson Mountains in the Northwest Territories; the herd is an important food source of the Native people of Fort McPherson and Aklavik.

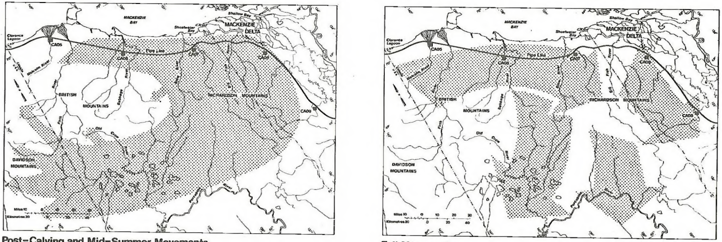
The proposed route crosses the critically important calving area in the northernmost part of the Yukon. Conflict would also arise with construction taking place during winters such as that of 1973-74, when animals overwintered on the North Slope.

Loss of habitat would occur on the right-of-way itself and on the sites of associated facilities, such as six compressor stations and 4 miles of roads, but these losses would be relatively insignificant. Recognizing that the area of concentrated caribou activity lies south of the pipeline, the disruption of certain topographic features, such as crossings of the Firth and other rivers, or passes between drainages, are considered to be important and loss of such features, especially within calving areas, could



░ Calving Grounds 1972
▨ Concentrate Calving 1972 ■ Compressor Station

Spring Movements
■ Compressor Station



Post-Calving and Mid-Summer Movements
■ Compressor Station

Fall Movements
■ Compressor Station

Source: Pipeline Application Assessment Group, 1974, p. 290.

Figure 3.1.2.7-1 Seasonal movements of Porcupine caribou herd

trigger unexpected behavioral responses. Fires are neither numerous nor extensive in northernmost Yukon (Barney and Comiskey, 1973), but any increase over their natural frequency caused by pipeline activities would be undesirable, for caribou avoid burned areas.

Both the construction and operation phases of pipeline development involve actions potentially disturbing to caribou. The former, particularly, includes increased human activity, the operation of heavy construction equipment, open ditches, strange objects, blasting and aircraft.

During the operational phase compressor stations and aircraft surveillance flights would be disturbing to caribou. There is also the very dangerous situation that would arise from pipeline breaks, when a variety of actions might be necessary at a particularly vulnerable time in a particularly sensitive area, such as the calving ground. The importance of avoiding the disturbance of caribou during calving cannot be overemphasized.

Both Geist (1971) and Skoog (1968) have shown the damage caused by aircraft harassment; the caribou's winter energy expenditures are raised, with a consequent decrease in the survival rate of the newly born young. The same has been demonstrated by Zhigunov (1968) for the closely similar reindeer in Russia. Disturbance is also damaging in summer, especially in the midsummer post-calving season when the animals' condition is depressed through nursing demands and the adverse combination of biting insects and summer heat. In effect, therefore, the winter to late-summer period (December 1 to July 31) is a particularly sensitive one.

The reaction of caribou to aircraft is not straightforward. Apparent reactions diminish markedly with increased altitude and also vary with other factors such as type of aircraft, habitat, herd size and time of year (McCourt and Horstman, 1974).

Some longer term disturbance might be caused by airstrips, access roads, equipment, stockpiles, and communication towers, but compressor stations would probably be more disturbing because of the continuous loud noise they would emit. Studies conducted by the Applicant, testing the effect of simulated compressor-station noise, have shown that caribou more than 220 yards from the source of noise are unlikely to be displaced. These results, however, relate to short-term trials. Whether caribou will adapt to long-continued noise emission or will be adversely affected was not addressed by these tests.

Present access and hunting pressures constitute no threat to the herd (DeBock and Surrendi, 1974), but this situation could change as a result of improved human access and increased travel. Such access could be provided by the Dempster Highway which will cross the Porcupine caribou herd's winter range north of the Peel River and its spring migration route through the Richardson Mountains. When the highway is completed, both the traffic on it and hunting from it could have a profound effect on the herd. The size of the herd could be reduced and the time and path of migration could be altered. The impacts of the proposed pipeline on the herd discussed above must, therefore, be viewed--and reviewed--in the context of these future changes. Of course, to the extent that the pipeline development would use the Dempster Highway, (about 30 miles), either directly in moving supplies or indirectly in generating incidental traffic, it would contribute to the interaction between caribou and potentially damaging forces.

Deer

Mule and whitetail deer are browsing animals found along the route of the proposed pipeline from the Peace River valley south. In areas disturbed by cultivation the whitetail has largely replaced the mule deer and would be the primary species of large herbivore along the proposed Monchy Delivery Line route. Winter range is the more critical habitat. There are route segments totaling about 40-50 miles for whitetail and about 70 miles for mule deer that appear to be important habitat areas (CAGPL, 1974b). Brushy stream valleys would be preferred by whitetails and more open upland brushy areas by mule deer, but the two species will winter together in some areas.

The influence of construction activities would extend beyond the right-of-way and roads and maintenance activities would no doubt prevent a return to the productivity levels existing in the area before pipelines were constructed. The existence of pipelines in the same corridor prior to construction of the proposed Arctic Gas Pipeline would have the effect of reducing but not eliminating adverse impacts of building the new pipeline. Where key habitat is concerned, the effects of such developments must be viewed as progressive and cumulative with a net loss that will not likely be fully recovered.

Wapiti

Wapiti (American elk) are grazing animals that occur along the proposed pipeline route in Alberta and southeastern British Columbia. According to CAGPL (1974b), the Peace River valley, the sections between the Athabasca and the North Saskatchewan Rivers and between the Porcupine Hills and the Kootenay River are important range. This indicates that the route traverses some 200-300 miles of habitat of which some unknown amount is key winter range. Any loss of key winter range is an adverse impact; however, there is a potential to restore and even improve some of this range by revegetation of disturbed areas with suitable grasses and forbs. In terms of numbers of animals, the loss of habitat would be less serious for wapiti than for deer, but in terms of biomass the effects would be similar.

Moose

Moose are to be found all along the proposed route except those portions passing through grassland and agriculturally developed areas in southern Alberta and southeastern Saskatchewan. The extent and quality of the wintering areas are the most important habitat considerations for moose. Wintering areas for moose may occasionally overlap wintering areas of other large herbivores such as elk and deer. Fires and logging have extended moose range in the north and agricultural areas have encroached upon the range in western Alberta. Winter pipeline construction in winter browse areas of riparian willow would have an adverse impact on individual moose survival. Direct destruction of habitat would result from clearing, grading, borrow pits, and construction of other facilities. An estimated 0.25 percent of moose habitat along the pipeline would be altered.

Kucera (1974) considered a corridor 20 miles (32 km) wide centering on the proposed pipeline route. The area of class 1, 2, and 3 habitat that fell in the corridor and the length of pipeline that crossed these areas were measured. Assuming that 0.05 square miles of terrain would be altered for every linear mile of pipeline, it was determined that within the corridor, 0.02 percent of good, 0.18 percent of fair, and 0.29 percent of poor winter habitat of moose would be affected. The class 3 habitat was included because although poor, it is nevertheless very important in the northern areas, being the only one available (Prescott and others, 1973). Altogether 0.25 percent of all classes of habitat would be changed by the project; some of it would be permanently lost (e.g., compressor station sites), and some of it might redevelop vegetation that would provide good forage.

Fire destroys the vegetation, but it also leads to vegetation succession which usually favors the moose (Leopold and Darling, 1953; Edwards, 1954; Peterson, 1955; and others). The frequency of fires in the area of the pipeline would probably increase, but not the amount of area burned (Hernandez, 1974). Small burned areas provide far better habitat for moose than large ones, because suitable shelter is usually close at hand (Peterson, 1955). Therefore, if anything, moose will possibly benefit from any increased incidence of fires.

Moose are found very near human habitations in most areas and, with the exception of hunting and deliberate harassment, are very tolerant of human activites.

Hunting is the main mortality factor in moose populations. If permitted, hunting by construction personnel could deplete the population so as to affect adversely the resident people who rely heavily on moose for food and clothing.

Moose are apparently not disturbed by aircraft flying above 600 feet elevation.

Pronghorn

Pronghorn antelope occur in southeastern Alberta and southwestern Saskatchewan. As for other large herbivores, winter range is more limiting than summer range. Pronghorn winter range appears to overlap that of deer to some extent in the Middle Sand Hills, Alberta, and Big Sand Hills and Frenchman River, Saskatchewan, areas. About the same amount of winter range would be lost as for whitetail deer and about the same loss of biomass in herd production could be expected as a result of pipeline construction.

Antelope are subject to severe losses, as much as 60 percent in severe winters of deep snows (CAGPL, 1974b).

Musk Ox

Musk oxen have been reintroduced on the north coast of Alaska and some have been seen in the Yukon. Low productivity and high susceptibility to hunting led to severe depletion of musk ox numbers throughout their range and the former Yukon population was exterminated. Complete protection was given to the musk ox in 1917 and the population is slowly recovering. Tener (1965) estimated the total Canadian population at 10,000 animals in 1965, and since then the population has increased both on the mainland (Kelsall and others, 1971) and on the Arctic Islands (Freeman, 1971). The musk ox is no longer considered an endangered species in any part of its range (Lent, 1971; Ingraham, 1970). In winter musk oxen are entirely dependent on range with thin, soft snow cover, or windswept areas (Tener, 1965; Spencer and Lensink, 1970). Animals might be driven away by combinations of disturbances and changes in snow cover characteristics resulting from winter construction traffic. The Yukon Coastal Plain, former range of the musk ox, is important for its reestablishment. Disturbance is the main probable adverse impact with some illegal hunting to be expected.

Mountain Sheep

Mountain sheep are present along segments of the proposed pipeline. The Prudhoe Bay Supply Line passes close to the Mount Goodenough herd of Dall sheep. About 20 miles of the route lies within 1 or 2 miles of areas designated as wintering or lambing areas. Disturbance factors rather than loss of habitat are the wildlife concern. The pipeline route adjoins the sheep's sensitive winter and lambing areas. Pipeline construction and operation could have considerable impact on the population. A compressor-station noise simulation study (McCourt, et al., 1974) showed that within 1 mile of the simulator, most of the sheep were displaced. Helicopter activity produced an even greater adverse reaction, and the report suggested further that a generally similar reaction might result from noise of construction equipment. The irregularity of blasting and its associated earth tremors are considered to disturb sheep even more.

The Kingsgate Delivery Line route will pass, along with an existing pipeline, through about 15 miles of bighorn sheep winter range on the east side of the Rocky Mountains. About twice that amount of summer range is crossed on the rest of the route to Elko. The presence of an existing pipeline would not eliminate the alteration of additional habitat; the construction of an additional line would constitute a further encroachment of effects which would be cumulative.

Proximity to rough terrain, which constitutes escape cover, is important to wild sheep. The closer this cover, the more valuable is a forage area to the sheep. The further the sheep must go from such cover to feed, the greater the dangers from predators. Planting of highly attractive forage in revegetation of pipeline areas could, by luring the sheep away from escape cover, increase vulnerability to predation.

Disturbance factors are difficult to assess because animals are adaptable and response will vary with experience of sheep and the circumstances. It seems safe to say that disturbance would occur with construction and operation of the pipeline; however, the consequences need not result in driving the sheep from their range or in reducing their survival.

Small Herbivores

Small herbivores would be affected more in terms of individual animals than would large herbivores, but, because of wide distribution and high reproduction potential, there would be no noticeable impacts on species populations. They do affect other wildlife dependent on them for prey or competing with them for forage and may interfere with attempts of man to revegetate or otherwise restore disturbed areas. Some small herbivores, such as the beaver and muskrat, are furbearers of economic importance.

Beaver and Muskrat

Beaver and muskrat are distributed in the Mackenzie, Peace, Athabasca, Saskatchewan, Missouri and Columbia River drainages crossed by the proposed pipeline route. Beaver tend to be found in the lakes and streams and muskrat in the marshes. In the Mackenzie Delta, the densities of beaver were estimated at about one colony per square mile and the density of muskrats, as indicated by an annual yield of fur, estimated at 50 per square mile. Beaver colonies per linear mile of the Mackenzie Valley were estimated at about 1/2 (Kucera, 1974). Actual habitat lost to pipeline would be small and might even be increased for muskrat, as by flooded borrow pits. A potential hazard exists from fuel and solvent spills which would affect insulating quality of fur and result in reduced survival in rivers.

Mice, Voles, Lemmings and Ground Squirrels

These animals constitute an important food resource for predatory birds and mammals. The populations of brown and collared lemmings and meadow voles can fluctuate from lows of 1-2 animals per acre to highs of over 100 per acre. Fluctuations in these and other prey species may occur as synchronous crashes over local or large areas and affect the numbers and movements of predators such as arctic fox and snowy owls. In the better drained areas porous backfill associated with constructing the pipeline would be colonized by some small herbivores such as ground squirrels. Others of this group would certainly be attracted to reseeded areas and might interfere with attempted revegetation of disturbed sites.

Rabbits, Hares and Pikas

These animals are important prey for predators, including man, and have a high reproductive potential and ability to attain high numbers after periods of scarcity. Two species, the Arctic and Alaskan hare [Kucera, 1974; but not listed by Banfield (1974) for Canada] are associated with the tundra areas and the snowshoe hare with the boreal forest. The white-tailed jackrabbit occurs in the Aspen parklands and on the plains in Alberta and Saskatchewan. Nuttall's cottontail is a Rocky Mountain species that extends into southwestern Alberta and southeastern British Columbia. Each of the above species would suffer some loss of habitat but populations would not be noticeably affected by constructing the pipeline. Rabbits can be an obstacle to successful revegetation of disturbed areas. Pikas of two species occur adjacent to the pipeline, one in the Richardson Mountains and the other in the Rocky Mountains, but would not be affected by the pipeline construction.

Carnivores

Where not harrassed and persecuted by man, the distribution and abundance of predators is directly linked to the distribution and abundance of the prey. Some species are more adaptable than others. The coyote represents one extreme and marten or black-footed ferret another.

Wolf

Wolves were distributed over the whole route of the proposed pipeline; however, in the Provinces they have been greatly reduced or eliminated in agricultural areas. Their abundance in the north is dependent upon the abundance of their prey (caribou or moose). A harvest of wolves by man can be sustained if the prey is not reduced and the wolf take is regulated. Aerial shooting accounts for nearly half the wolves taken in Alaska and the response of wolves in the Northwest Territories indicates they are being harassed by aircraft. Dens are in well drained areas in hillsides or on eskers. Dens are often enlarged fox dens, as both species require similar sites for denning. The proposed pipeline route includes potential denning areas near Travaillant Lake and in the upper Mackenzie Valley. Some loss or restriction would occur, but increased killing of wolves would be the most severe impact expected, mainly through the indirect effects of increased human access to the areas. Wolves would travel roads and pipeline right-of-way and benefit in hunting success in areas where prey animals were attracted by revegetation.

Arctic and Red Fox

While other food sources may be utilized, foxes depend largely on the small herbivores as prey. Numbers of fox tend to fluctuate with prey populations, but lag slightly behind the prey fluctuations. Arctic foxes inhabit the tundra areas and their number would be expected to follow fluctuations in the number of the brown and collared lemmings; similarly, the more widely distributed red foxes would suffer with the crash of a lemming and vole population but seem successful in shifting to large prey, such as birds and rabbits. Foxes are also scavengers, attracted to kills of larger animals by predators such as the polar bear and wolf and by camp refuse.

As with wolves, where suitably drained denning areas would be limited, foxes would lose some breeding habitat by the construction of the proposed pipeline. Within a half-mile radius of each of the compressor stations, noise would interfere (because foxes hunt largely by sound) to an unknown extent with hunting success or the use of foraging areas. Fur prices would be the principal factor in human exploitation of fox populations for fur. Building and operating the proposed pipeline would not have a measurable direct adverse impact on foxes, wolves or coyotes; in fact, revegetation and clearing of land for pipeline right-of-way would have a favorable impact--attracting and increasing vulnerability of prey. Indirectly, increased human use and access following building of roads and the pipeline would increase hunting or trapping pressure on all wild canids.

Grizzly Bear

Grizzly bears range over the tundra and south into western Alberta and along the Rocky Mountains to the Canada-United States border. In Alberta the numbers are less, and the proposed pipeline route south of the Peace River would not likely encounter any of these bears. Some grizzlies hibernate from November to April in dens dug in well drained slopes or in existing natural caves. Of the 18 den sites identified by Quimby and Snarski (1974) only five were in natural rock shelters. Others were dug by the bears and many additional natural caves were not used. Five dens were freshly dug.

Although there is circumstantial evidence that some bears den on the coastal plain (probably in river valley slopes), most of the bears occurring there during the summer den in the foothills (Pearson, personal commun. cited by Kucera, 1974).

Suitable den sites do not limit the numbers of grizzly bears. On a four-point scale of Nolan and others (1973), 135 miles of the best grizzly habitat (Class 1) is crossed by the proposed Prudhoe Bay and Richards Island Supply Line routes in Canada; 122 miles of these routes is Class 2. In the Mackenzie Valley the proposed route parallels Class 3 habitat in the McConnell Range. The significant impact of a route through this habitat would be increased susceptibility to disturbance or conflicts resulting from human contact that would result in destruction of individual bears. Hunting pressure would increase, largely because of the desirability of a grizzly as a trophy.

Any increase in the presence of humans and their developments, whether directly attributable to, or precipitated by the pipeline project, would undoubtedly result in eventual extermination of the grizzlies from some areas, no matter what management policies were followed. People in general do not get used to a powerful potentially dangerous predator like a grizzly living "in their backyard". Macpherson (1965) has discussed at length the situation of barren-ground grizzlies in the Northwest Territories; killing of bears continued despite complete legal protection.

Response of grizzly bears to aircraft indicates present populations have been harassed by aircraft. Whether increased aircraft use associated with pipeline construction and maintenance would stress the bears to the extent that feeding and breeding would be disrupted is not known.

It is concluded that construction and operation of a pipeline would entail a significant decrease in the grizzly bear population along the proposed route.

Polar Bear

Polar bears occur along the coastal areas from Herschel Island to the Mackenzie Delta and on Richards Island. They come to shore and would be within the influence of the pipeline occasionally (in late summer or fall) when drift ice approached shores and became fast. In the Northwest Territories hunter harvest is regulated under a quota system and a similar system is anticipated for the Yukon Territory. Bears would be destroyed when they become dangerous to people. Bear control and illegal shooting, which might be accelerated by pipeline construction, would have an adverse impact on this species.

Black Bear

Black bears are more widely dispersed and the impact of the pipeline on the population status of the species would be negligible.

Wolverine

Wolverine conflicts with man seem inevitable and are usually resolved by eliminating the wolverine. Krott (1959) estimated the minimum area necessary to satisfy the territorial requirement of the species to be 300 square miles; Quick (1953) estimated a population density of 1 per 80 square miles. Canadian fur trade records indicate a gradual decline in catch of wolverine. The wolverine is not considered rare or endangered in Canada, but it has been extirpated over much of its former range. The females do not breed until 2 or more years old and the average litter size is 2.5. Construction and operation of the proposed pipeline would result in a further reduction in the number of wolverine. Assumption of a 10-mile pipeline corridor width as the impact area is too conservative. Assuming 1 per 300 square miles and 900 miles of pipeline corridor 10 miles wide, the affected population would be 30 animals. By way of comparison, this number equals nearly a third of the average number of pelts exported annually from the Northwest Territories (Kucera, 1974).

Marten

Marten are curious and easily trapped. The value of their pelt has varied from $8.33 to $100 each since 1940. In 1971-72 56,231 pelts were traded in Canada. They are typical in the climax forest, and fires and clearing of forests reduce their habitat. Their home ranges are small.

Kucera (1974) calculated on the basis of a saturated population and a density of 2 per square mile that no more than 10 percent of the marten along the route would be eliminated if the pipeline were built. Barring the possible increase of fire associated with construction and operation of the pipeline, marten habitat would be reduced for about 2-5 years, after which habitat would be improved. There would be no measurable adverse effect on marten other than increased vulnerability to trapping due to improved access.

Fisher

Fisher are a larger relative of the marten requiring ten times as much territory. With slower reproductive potential, requiring two years to reach breeding age and with about the same sized litters as marten, the fisher would be more vulnerable than marten to loss of habitat and trapping pressure associated with pipeline construction and operation.

Weasels

Ermine and other weasels, having more restricted home ranges and occupying more diverse habitat types than marten, would temporarily lose habitat through the construction of the pipeline along most of the proposed route. Habitat conditions for prey would likely improve with time after construction, and the higher reproductive potential (litter size averages about 6) would make the impacts on weasel populations less than for marten. Similarly other mustelids, such as the badger and skunk, would benefit by increases in prey along the pipeline right-of-way after construction.

Insectivores

Small size and high rates of metabolism of insectivores make them vulnerable to the effects of disturbance and to fluctuations in their food supply. Food of shrews is largely invertebrate but includes small herbivores and even other shrews. Bats are more strictly insectivorous and migrate or hibernate to survive seasons of food shortage.

Shrews

Shrews have a high reproductive potential and are widely distributed, so habitat loss might be important in numbers of individuals affected but effects on species populations would be negligible. Along the proposed pipeline route five species are found and frequently two or three species may be taken at the same site. The water shrew has the most restricted distribution and the masked shrew the widest. The ranges of the Arctic and dusky shrew overlap, but a short distance south of 60° N. latitude the dusky shrew replaces the Arctic shrew. Because vegetation duff (for concealment and a favorable microclimate) would be slow to accumulate following pipeline construction, shrews would suffer a more persistent loss of habitat than other small mammals. This might be compensated for to some unknown extent by greater food production or availability along the "edge" created by clearing pipeline right-of-way and associated areas.

Bats

Bats feed largely on the wing in openings between, or under canopies of, forest trees. To the extent that cleared pipeline right-of-way would provide favorable foraging areas for some, such as the large brown and little brown bats, the construction impact would be beneficial. Destruction or disturbance of winter hibernation quarters would have adverse effects on populations of the beneficial little brown bats.

Marine Mammals

Use of the proposed route could have an impact upon marine mammals. There is a potential danger of fuel leaking from storage tanks and barges and entering the marine environment. Barging operations in the Beaufort Sea, and the Mackenzie River and Bay could be expected to have accidents. Of major concern are concentrations of marine mammals as on the calving grounds of white whales in Shallow Bay.

Birds

Direct and indirect impacts, associated with the construction and operation of the proposed pipeline, would probably affect in some way most, if not all, of some 320 species of birds that breed in, migrate through, or visit areas along the proposed route. Most of the impacts would have no apparent effects on species populations. Local densities of some ecotone species such as juncos would even be increased within a few years after the initial disturbance of construction. Other species would lose habitat available to them, but for widely dispersed breeding populations broadly distributed in range, the habitat loss will be insignificant. A great potential does exist for significant adverse impacts where breeding populations are concentrated on nesting grounds, in critical feeding and resting areas, and even in migration. Adverse effects on these populations would be caused by disturbance, habitat destruction, and losses from pollution, migration hazards, and increased predation, including that by man and domestic animals, on nests, young and adult birds.

In this discussion, emphasis will be placed on those species which demand the greatest attention because of economic, esthetic, recreational, or cultural value--snow geese and whistling swans. Some species will be grouped for discussion: other waterfowl, upland game birds, shorebirds, and songbirds. Birds of prey are discussed under "Rare and Endangered Species."

Lesser Snow Goose

Protected by the Migratory Birds Convention Act, the lesser snow goose serves as an important food and recreation resource for man. From the Mackenzie Delta, through southern Alberta and Montana to Oregon, and California United States, hunters eagerly seek it each fall.

The following information is based on a report of Pipeline Application Assessment Group (1974).

Each spring, thousands of birds return from their wintering areas in the southern United States by way of the Mackenzie Valley. They require open water, and they rest, feed and mate on the partly flooded river islands and on nearby lakes after the breakup of the river ice. Their destinations are the few suitable nesting areas at the mouths of the Anderson and Smoke Rivers (Northwest Territories), Banks Island, and a few small scattered sites near the marine interface of the Mackenzie Delta. Snow geese are colonial nesters, returning each year to the same areas. Such areas have extensive brood-raising capabilities.

By mid-August the geese gather on the islands of the Mackenzie Delta in flocks of some 20,000 to 50,000 birds, totalling 500,000 in some years. They then fly westward to the North Slope of the Yukon Territory and northeast Alaska. Here they feed intensively on berries and sedges for 4 to 6 weeks to prepare themselves for the long migration to the wheat fields of southern Alberta and beyond. They usually fly non-stop the 800 miles between the North Slope and Hay Lake in northern Alberta (Barry, 1967).

Because of the shortness of the northern summer, the available nesting season is short, with barely enough time to raise young to flight size before the fall freeze-up. Interruption of the birds' normal movement and behavior patterns, especially their energy-building feeding period in late summer, could mean that both adults and juveniles might not have the stamina to complete their southward migration.

The specific studies sponsored by the Applicant recognize most of the environmental problems associated with snow geese (Gollop and Davis, 1974; Schweinsburg, 1974b). Simulated compressor-station noise was shown to disrupt the birds' movement patterns, and birds as far as 3 miles away from the source of noise were displaced. Eventually, however, some birds returned to within 1.5 miles of the noise source. Aircraft disturbed snow geese up to 9 miles away.

Comparison of the boundaries of the Kendall Island Migratory Bird Sanctuary (Migratory Bird Sanctuary Regulations) with the Applicant's proposed right-of-way shows that the Richards Island terminal falls inside the Sanctuary. In contrast, the Applicant's smaller-scale Wildlife Series Maps show that the terminal is outside, although the associated borrow pit is shown in the Sanctuary. Parts of the Sanctuary are used by snow geese for breeding, molting and fall-staging (Barry, pers. comm.), so the development of a pipeline terminal, together with the gas production and gathering system and associated noise and activity, could have a profound adverse impact on the use of these areas by the geese. The Sanctuary cannot be entirely avoided, of course, because it contains part of the gas field, and some collecting and processing facilities are bound to be developed there by the producers if the field is tapped. Industry is already in the Sanctuary under permit by the Canadian Wildlife Service. The solution to a possible conflict between geese and the development appears to lie in locating the production facilities so that sensitive geese areas are avoided, or where this is not possible, in employing operating procedures that are acceptable to the appropriate regulatory agencies.

From the islands of the Mackenzie Delta, flocks of up to 500,000 geese fly to the coast of the Yukon and northeastern Alaska, where they feed intensively all over the tundra slopes to and including those of the foothills. Jacobson (1974) indicates that much of this critical feeding area would be lost if activities, including aerial flights over the area, were permitted between mid-August and mid-October. The consequences of this loss of feeding habitat to the population would be a failure of birds to build up energy reserves needed for the long fall migration and a poorer survival that might well precipitate a sharp decline in the population. If geese arriving at Hay Lake are in good condition, their stay is short, but if in poor condition they may stay till freezeup. The pipeline would increase potential disturbance in the Hay Lake area, an area already being squeezed by oil and gas development. The proposed activities and new development with pipeline construction and one compressor station would be additive. There is not enough known about the behavior of the population segments to predict with any confidence the severity of the impact in numbers or percentage of the population.

Swans

Whistling swans that winter on the estuaries of Chesapeake Bay and Currituck Sound in Maryland, Virginia, and North Carolina breed in the Canadian Arctic and North Slope of Alaska. This Atlantic Coast population of swans was estimated at 62,800 in 1972.

Swans defend large nesting territories, up to 80 acres per pair; so, the actual area of ground that would be occupied by the proposed pipeline right-of-way, compressor stations, roads, airfields, heliports, communication towers, and wharves would not displace large numbers of breeders. However, swans are very susceptible to disturbance by aircraft, compressor stations, and other activities, as indicated by the avoidance of areas within 5 miles of drilling rigs by molting and nonbreeding swans, though nesting swans within two-thirds of a mile did not desert the area until after their young had hatched. Swans are also relatively susceptible to collision accidents; 65 percent of more than 1,000 mute swans found dead in England were collision casualties and two-thirds of these were killed by wires. Where fuel and other petroleum products are handled and stored there is a threat of fuel spills. Fuel spills into water courses in concentration, molting, and nesting areas are a direct hazard to swans and cygnets and could spoil large areas of nesting habitat in the Mackenzie Delta areas. (Jacobson, 1974).

Critical spring migration habitat is identified by Jacobson (1974) as open water around islands and sandbars in the Mackenzie River between the Arctic Red River and Fort Good Hope. Swans congregate here in large numbers in May. As with snow geese, energy reserve, whether for migration or nesting, is so critical that any disturbance could affect adversely the reproductive success of breeding swans. Excessive movements caused by disturbance and resulting in moving north too soon would drain the birds' energy reserves. Insulation and fat reserves must be adequate for successful nesting and survival of young. Survival of precocious young of other avian species even after hatching has been directly correlated with lipid contents of the egg. This could be a factor in the observed high cygnet mortality in the first weeks of life attributed to starvation and chilling cited by Jacobson (1974). Swans would be susceptible to any pollutants reducing plumage insulation efficiency.

Critical nesting and molting habitat for swans in the Blow River-Shallow Bay area and migration habitat on the Mackenzie River segment below Fort Good Hope are identified by Jacobson (1974) as being most susceptible to disturbance and adverse impact. The sources of the potential impacts are the proposed construction and operation of two compressor stations, an airstrip at Shingle Point, and the increased air traffic, particularly between Shingle Point and Inuvik. There are also oil storage and handling points at Shingle Point and on the west channel of the Mackenzie River in the delta. At Fort Good Hope and in the critical habitat below, the Applicant plans three compressor stations, four wharf and fuel areas, three landing strips, and four heliports. Without great precautions the swan population would suffer adverse impacts that could result in catastrophic nesting and cygnet losses in years of less favorable nesting conditions.

Other Waterfowl

Sea ducks that nest along the Beaufort Sea coast include the colonial nesting eiders and the more dispersed nesting oldsquaw ducks and, some, like the scoters, that fly inland to nest in forested areas along shores of freshwater lakes and streams. All are dependent on the coastal ecosystem for the molt, feeding, and migration. Destruction or alteration of sheltered coastal lagoons or associated sand and gravel bars, spits, or offshore islands would limit critical habitat, as would any changes in fresh-salt water regimes, siltation, and pollution that would reduce the food base consisting of a complex of invertebrates and fish produced in the estuarine areas. Oil pollution would adversely affect this habitat. It would also result in deaths for rafts of molting sea ducks. Aerial disturbance is less critical than for snow geese and swans, but is still considered an adverse factor. Human disturbance, particularly in the nesting colonies of eider, would have an adverse impact on nesting success and could be a factor in eventually reducing the population.

Potential hazards to sea ducks from building the proposed pipeline include the coastal facilities for transport, handling, and storage of oil at Komakuk Beach and Shingle Point. Siltation effects from borrow-pit operations on drainages above Clarence Lagoon and the alluvial drainage of the Malcolm and Firth Rivers would impact the food base inside the Nunalak Spit. Because of the effects of petroleum oils on the insulation qualities of bird plumage, there is considerable concern about accidental discharges of fuel oil, waste oils, and other light petroleum or organic solvent materials that might spread over the surface of water.

Other diving ducks feed largely on invertebrates in coastal areas, but scaup are the most important because of the numbers produced in the area along the proposed pipeline route from the Yukon coast through the Mackenzie Valley. This species comprises over half of all the ducks along the Mackenzie Valley (Jacobson, 1974). The potential hazards mentioned for sea ducks apply to this species in the coastal areas. Density in the Mackenzie Valley averaged about 2 per square mile. Other diving ducks in the Mackenzie Valley include canvassback, goldeneye, and buffelhead. Redhead and ring-necked ducks also occur; the northern limit for the breeding redheads is near Fort Resolution and for the ring-necked duck near Fort Simpson.

The surface-feeding or dabbling ducks common along the route are pintail, American wigeon, and green-winged teal. Of these the pintail is the most widely distributed, occurring across the treeless portions of the Yukon coast and the Mackenzie Delta as well as along the Mackenzie Valley. Typical Boreal Forest areas here have waterfowl densities of about 14 per square mile. The breeding range of the blue-winged teal extends south from Great Slave Lake.

No breeding density figures are available for the proposed pipeline corridor south of the 60° N. latitude through the Provinces. Except for stream crossings the proposed route generally avoids water areas; however, inspection of maps (scale 1:250,000) indicates that roughly 150-200 miles of total corridor area would be reasonably productive of waterfowl, and some production along perhaps two to three times that corridor length is expected. Assuming impacts on nesting ducks would extend an average of 1 mile on either side of the pipeline, and the average for reasonably productive areas to be 10 per square mile over the 1,000 miles of pipeline south of Travaillant Junction, a total of 20,000 ducks of all species would nest in this corridor. The potential hazards can be summarized as follows: (1) Increased nest destruction and disturbance which could affect up to 10 percent of the nests, and would be additive to normal losses, which are variable. Estimated normal losses could be about 50 percent. (2) The influence of disturbance on feeding and movements, the consequences of which are physiological increase in vulnerability to normal factors and a potential decrease in reproductive capacity affecting recruitment in the population. (3) Alteration of the habitat could have a beneficial impact by creating additional habitat (e.g. flooding of borrow pits), or, particularly in prairie areas, by improving existing habitat. Alteration of the habitat also could have an adverse impact through destruction or pollution of existing habitats (e.g. oil covered water represents both destruction of habitat and a mortality factor).

Upland Game Birds

Loss of existing habitat through clearing of right-of-way and possible increased incidence of fires could be adverse or beneficial, depending upon the bird species, size of burned areas, time, and other factors. In general upland game birds are benefited by "edge effects" where cover and feeding areas are in different vegetation types. The successional events in burned areas or revegetation strategies in cleared areas would favor some species over others. The adverse impacts other than destruction of some nesting habitat at time of construction would be increased vulnerability to predators hunting the cleared areas. No detectable changes would occur in overall species populations, though subsequent monitoring activities along the pipeline route could ultimately be expected to reflect an increase. Habitats of upland game birds do not have the same vulnerability to pollution as do the wetlands that are essential to geese and ducks, so possible spills of petroleum products would have little impact on upland game birds.

Shorebirds

Shorebirds, including gulls and terns, are sensitive to pollution effects on habitat. They migrate considerable distances, and energy storage-energy consumption balance can be critical, particularly to those species nesting in the Arctic. There is also a possibility, although not well documented, that some species in this group are highly vulnerable to effects from habitat pollution. Most shorebirds are more tolerant of human and aircraft activity than are waterfowl, but effects of constructing the proposed pipeline would include progressive and cumulative loss of habitat.

Song Birds

Song birds as a group contain species occupying all the vegetative communities crossed by the proposed route. Construction of the pipeline for this group would entail loss of habitat for many species, but at the same time might ultimately increase the total number of breeding pairs of all species along the pipeline corridor by diversification of the existing plant community patterns and composition. The effects of "edge" would increase ecotone species such as juncos in forested areas.

Rare and Endangered Species

Species of mammals and birds discussed here are indicated by asterisk in tables 2.1.2.7-9 and 10. They are discussed relative to provision of the U.S. Endangered Species Act of 1973. Parallel Canadian legislation is expected relative to implementation and enforcement of import-export provisions under the Convention on International Trade in Endangered Species of Wild Fauna and Flora. The U.S. law encompasses all species of plants and animals and provides for protective measures under two categories, "endangered" and "threatened". Consistent with this Act, the term "species" includes recognized viable races or subspecies. Whooping Crane, Eskimo Curlew, and two races of Peregrine Falcon (*Falco peregrinus tundrius* and *F. p. anatum*) are listed as the endangered species of birds, and the Black-footed Ferret, the Northern Kit Fox (*Vulpes velox hebes*) and the Northern

Rocky Mountain race of the wolf (Canis lupus irremotus) as the endangered species of mammals that could be encountered along the proposed pipeline route.

Endangered Species of Birds

Peregrine Falcon

Impact from the proposed pipeline construction and operation would be greatest on the Peregrine Falcon and some additional birds of prey included with it in surveys of the pipeline route north of the 60th parallel by the Canadian Wildlife Service. These species are discussed together as "Endangered Birds of Prey", in the following excerpted material from report of Pipeline Application Assessment Group (1974):

> Northern Canada is widely recognized to be one of the last major refuges for many species of North American raptors. Highly sensitive to the disturbance and development associated with man, the numbers of these birds of prey have decreased drastically in central, southern and eastern North America. Both the purely wilderness species--Gyrfalcon (Falco rusticolus) and Golden Eagle (Aquila chrysaetos)--and the normally more widely distributed species--Peregrine Falcon (Falco peregrinus), Merlin (Falco columbarios) and Bald Eagle (Haliaetus leucocephalus)--have been the victims of toxic chemicals, falconers, egg collectors and hunters, to the extent that the Peregrine, for example, is today in danger of extinction. Surviving populations of these species in northern Canada are unique, and are both nationally and internationally important. They are protected under the Game Ordinances of the Territories and Provinces.
>
> Environmental concern arises because the proposed gas pipeline route passes through wilderness areas that provide nesting sites and breeding habitat for these birds. The potential for conflict is two-fold: nests and nesting sites may be destroyed; and the disturbance of pipeline activities may drive birds from their young, from their nest, or from their living space (habitat).
>
> The difficulty of avoiding such conflicts is complicated by the need to avoid public disclosure of location of nest sites and the lack of precise knowledge of the minimum distance required to prevent disturbance. The latter aspect is further complicated by most of the species being migratory. The critical nesting period begins around mid-April and may extend to the end of August (Fyfe and Kemper, 1974). In some years, however, Gyrfalcons may spend the entire winter in the vicinity of the nest site and begin nesting in early February. Young are usually fledged by the end of July, but this varies greatly (Cade, 1960). The species involved fall into two groups: the tree-nesters, such as the Bald Eagle; and the cliff-nesters, such as the Peregrine Falcon, Gyrfalcon, and Golden Eagle. Both groups, of course, must have suitable nesting sites and adjacent food supplies. This combination is usually scarce, in some areas trees are plentiful, but fish--the major food of bald eagles--are limited, because only certain waterbodies are suitable sources. These are the outlets or shores of large rather shallow lakes, such as Trainor, Trout, Chick and Travaillant Lakes, or the many lakes in the Mackenzie Delta, (and in Alberta Bistcho Lake).

Similarly, the mountainous areas possess numerous cliff faces but few have nearby sources of ducks and shorebirds favoured by Peregrine Falcon, or of ptarmigan and hares favoured by Gyrfalcons. The rare combination is found in parts of the Richardson Mountains and the Norman Range where abrupt cliffs tower above adjacent lowlands. This habitat can also occur along river valleys, certain stretches of the Mackenzie and its tributaries and the rivers of the Yukon North Slope. Territorialism of the birds themselves further restricts their use of available habitat. Nesting pairs are normally more than two miles apart, and a singular pair of some species may use alternate nest sites through the scarcity of prey. An apparently empty nesting site, therefore, does not necessarily signify a surplus of sites that are expendable.

Annual surveys of raptor nesting sites by the Canadian Wildlife Service (CWS) in the Western Arctic for 1972, 1973, and 1974 focused on the proposed pipeline route (Fyfe and Kemper, 1974). Surveys were also made by the Environment Protection Board in 1972 and 97 sites were discovered. The detailed results of these and most other raptor surveys are maintained by the CWS in Edmonton, but the locations of sites are not publicly divulged. Disturbance data are not plentiful (Watson et al., 1973; Fyfe and Kemper, 1974) but have permitted the formulation of tentative guides to precautionary measures.

Jacobson (1974) cites a personal communication from the CWS raptor biologist, R. Fyfe, that raptor surveys along the proposed pipeline right-of-way indicated potential conflicts still exist between active peregrine falcon eyries and the proposed locations of facilities or construction activities. These conflicts involve the coastal Prudhoe Bay Supply Line, the alternative Interior Route, the Richards Island Supply Line and the Main Line north of 60° N. latitude. Disturbance during the reproduction season is the major source of adverse impact expectable from pipeline-related activities. Since winter construction is planned, construction activities should not affect reproduction activities between April and September; the concern is related to location of facilities and their servicing. Such a conflict appears to exist at Campbell Lake. At Inuvik, only 10 miles from the lake, there are planned three airstrips, a wharf, a supply depot, a helicopter pad, a fuel storage facility, and a communication tower. Where the Dempster Highway passes around the east side of Campbell Lake a compressor station, a communication tower, a heliport and a borrow pit are shown in the Applicant's plans. These additions to the current level of human activities and facilities have great apparent potential for adversely affecting the endangered peregrine.

Predicting the response of a given pair of peregrines to disturbance is impossible; there are examples of pairs showing rather widely ranging tolerances to human presence and activity. Destruction of eggs and young might result from human disturbance levels tolerated by some pairs, so, we must conclude that there would be an adverse impact on the endangered Peregrine Falcon. The loss of a productive eyrie or pair of birds would constitute a significant impact.

Eskimo Curlew

Eskimo Curlew is an endangered species of bird that once bred in the District of Mackenzie. The present breeding range and migration routes of any surviving segment of this population are unknown. There is no reason to suspect that the construction and operation of the pipeline would ever encounter or affect this species beyond the remote chance of an accident involving some pipeline facility such as a communication tower.

Whooping Crane

The breeding range of the whooping crane is Wood Buffalo National Park in northeastern Alberta; the remnant population of about 50 birds migrates to the Aransas National Wildlife Refuge on the Gulf Coast of Texas to winter. In migration birds might cross the proposed route in Canada but the major migration route identified would cross to the east between Mileposts 75 and 180 after the pipeline route had crossed into the United States. Again the communication towers would be the greatest hazard to migrating birds, and only the remote chance of a whooping crane striking one along the Monchy Delivery Line between Caroline Junction and the Canada-U.S. border exists. As no critical habitat or staging areas exist along the proposed route, construction and operation of the pipeline would not be expected to affect this species.

Endangered Species of Mammals

Banfield (1974) lists the northern kit fox and black-footed ferret as extinct and the northern rock mountain wolf as very rare. The Monchy Delivery Line segment of the proposed route would pass through former range of all three endangered species.

Black-Footed Ferret

This endangered species is generally associated with prairie dog towns, yet the reported distribution of the former extends much further into Alberta and Saskatchewan than does that of the prairie dog which is now limited in Canada to a small area along the Frenchman River near the Canada-United States border. This would suggest that the distribution of the black-footed ferret was not limited by that of the prairie dog. Since habitat including the prairie dog as potential prey exists, a reappearance of the endangered ferret would not be too remote a possibility, and certainly a potential exists for future reintroduction of this species. The length of time since the last speciman was encountered is not proof of absence. The route of the proposed pipeline passes very close to, if not through, prairie-dog colonies. The most likely place to encounter this endangered species would be in such a colony and the destruction of any ferrets or the disruption of any colonies where ferrets still exist would be an adverse impact of some consequence.

Northern Kit Fox

This species has also been listed as extinct by Banfield (1974), but this does not exclude the possibility that it still exists in the area planned for the pipeline. Other than the remote chance of the pipeline destroying a den, the proposed route would not have an adverse impact on the status of the species.

Northern Rocky Mountain Wolf

The range of this species in southeastern Alberta would be crossed by the pipeline. Being rare, and with no reason to expect any greater chance of its recurrence along the proposed route, no adverse impact is expected.

3.1.2.8 Ecological Considerations

Major Ecosystems

The proposed pipeline system, by reason of its geographic scope in Canada, would affect the ecological functions of many of the major North American ecosystems, as listed previously (Section 2.1.2.8).

At first order scale within the total biosphere, these include the Marine Ecosystem of the Beaufort Sea; the Tundra Ecosystem; the Forest-Tundra Ecosystem; the Boreal Forest Ecosystem; the Subalpine Forest Ecosystem; the Interior Wet Belt Forest Ecosystem; the Parkland Ecosystem; the Grassland Ecosystem; and the Freshwater Ecosystem of lakes and rivers.

Ecological impacts, with respect to vegetation, fish and wildlife, and physical components of the environment have been discussed in several parts of this Statement (Section 3.1.2.1 to 7) and general comments made concerning major ecosystems (Section 2.1.2.8). Although some arctic ecosystems have been discussed (Bliss, and others, 1973; Environment Protection Board, 1974) little is yet known of the many major ecosystems traversed by the proposed pipeline route that permits valid predictions of impacts. Pipeline and related impacts on specific components of arctic/subarctic ecosystems have been treated by Bliss and Wein (1972) and Bliss and Peterson (1973) but no assessments have been made at the total ecosystem level.

The present state of knowledge, which does not enable the prediction of many secondary and tertiary consequences of a primary effect on a single component, holds little promise for evaluation of the potential total effect on a single ecosystem, much less the total effect on interrelated ecosystems. It is certain that the total significant impact of the proposed pipeline construction and operation would be much greater than the simple additive effects of individual project components on individual environmental components. At the scale of the proposed pipeline the nature of the total impact cannot be adequately described and certainly not quantified.

The major ecosystems cover large areas and the proposed pipeline project is not a direct threat to any. All of the marine, freshwater, tundra and forest systems have transcontinental distribution in North America as far south as the Boreal Forest Ecosystem inclusively. These systems are in fact circumpolar in distribution. At second order scale, as for example, the Ice Affected Coast and the Inner Continental Shelf sub-systems of the Marine Ecosystem or the Alpine, Herbaceous Coastal and Low Shrub-Heath sub-systems of the Tundra Ecosystem, the systems are still so extensive that the proposed pipeline project per se could have only minor overall impact.

The impact would, however, be unequal. At one extreme, at the northern end of the pipeline system, the project would be the first major invasion of the Herbaceous Coastal Tundra which is limited in area and sensitive to change. At the southern extreme, in Parkland and Grassland Ecosystems the project would represent an incremental attrition to systems both extensively and intensively perturbed and take a further toll of the shrinking resource of systems in their natural state.

Third order subdivisions of ecosystems, and repeated subdivisions beyond, bring the natural communities to a scale small enough relative to pipeline and facilities that impact could be locally major. At such scales the impacts would probably be on local representatives of widespread communities of the same type, but there is a potential hazard to unique ecosystems now unknown.

The threat to major ecosystems lies in the total set of human influences of which the pipeline system would be only one part. The Applicant has proposed construction of a trunk pipeline and facilities to transport Alaskan and Canadian gas and it appears valid to evaluate only the effects of that project. However, this would be unrealistic since the pipeline would connect to gas gathering systems which would connect to production wells in gas development regions, roads would be built by industry or governments, and all of these developments, and others, which would occur in a related sequence, would have major cumulative effects on the same ecosystems.

Ecosystem Productivity

Marine Ecosystems

The potential impact of the proposed pipeline on biological productivity of the Ice Affected Coast and Inner Continental Shelf Ecosystems appears to be minimal. Marine shipping and air traffic, if uncontrolled, could disturb sea mammals, such as seals and polar bear, and migratory waterfowl and shore birds which nest, feed, moult and stage for migration on the seashore or offshore islands. Such disturbance cannot now be translated into losses of biomass production.

The food web could be threatened by introduction of accidental or deliberate discharges of oil, methanol pipeline test fluid, or other toxic materials into the sea or into streams draining into marine waters. Disruption of the rate of primary production of the phytoplankton population and of the planktonic invertebrate consumers would affect the entire food web adversely. The threat would exist primarily during the construction phase and mainly around wharf and stockpile sites. The infrequency of contamination, its localized nature, and the dilution potential of oceanic circulation would be expected to avoid any long-term effects on productivity.

Biologically essential mineral nutrients are deficient in arctic marine waters and their introduction through waste disposal, fertilizers employed in revegetation programs, or other contaminants could induce increased productivity and imbalance in the ecosystem. These effects, should they occur, would be transient during the short-term construction phases. Polar bear, the dominant marine carnivore, could suffer losses of productivity through destruction of denning sites or increased hunting pressure if hunting were not controlled. The effect of productivity losses of a major carnivore on the productivity of the ecosystem of which it is a part cannot be estimated.

Freshwater Ecosystems

Streams and lakes would be subject to the same pollution and food web effects as marine waters. Individual lakes or streams could be more seriously affected on a longer term basis depending upon the magnitude of the disruption in relation to size of the water body. Siltation resulting from stream crossings, or other erosion induced by construction, would affect productivity primarily through reduced light for primary production of phytoplankton and disturbance to fish spawning beds. The overall productivity effects should be minor but could be locally serious in instances that cannot be predicted.

Principal waterways, such as the Mackenzie River, would be subject to longer term, chronic effects from the cumulative physical and chemical changes resulting from the human influences in the watershed. Pollutants transported to the Mackenzie Delta would have severe impact on productivity of the biologically rich and sensitive aquatic ecosystems of the delta area.

Oxygen depletion in ice-covered lakes is a potential threat to overwintering fish populations and may result either from eutrophication of the lake or by water removal for such construction activities as the building of snow and ice roads. Lakes large enough and deep enough to sustain overwintering fish populations are probably capable of controlled water drawdown without incurring oxygen depletion but the problem is one of concern.

Tundra Ecosystem

Reduction of the rate of primary production or of the total annual accumulation of plant biomass would be minor as a consequence of the proposed pipeline construction. Production would be eliminated on all acreages occupied by permanent facilities (see Section 3.1.2.6) and reduced in the short term on the pipeline right-of-way, on any permafrost areas where erosion processes are initiated, or on areas subjected to oil spills or other toxic chemicals.

Although natural processes of colonization and plant succession are slow in tundra communities, productivity of this ecosystem component would be expected to recover in a few years to a few decades. The lower summer soil temperature over the refrigerated gas pipeline would predictably further retard return to full productivity on that localized, linear area. It is improbable that the decreases of plant productivity would have any major impact on the food web or on the habitat requirements of any of the other biological components of the tundra ecosystem outside the land areas directly perturbed. On the right-of-way, short-term reduction of productivity of decomposer populations of the soils and small herbivorous mammals, such as microtine rodents, would occur.

Short-term increases in productivity could result from the addition of nitrate and phosphate fertilizers in revegetation programs. Tundra soils, as with arctic waters, are deficient in these minerals and productivity response to their addition can be dramatic both in producer and consumer populations.

There being no apparent threat to primary food production nor to small mammal consumers, total impact on tundra productivity depends largely upon the effects of the proposed project on large herbivores, as caribou; carnivores, as wolves; omnivores, as the barren ground grizzly bear; and upon the highly productive resident and migratory bird populations which occur on the tundra in enormous numbers. Impacts of construction and operations on these and other animals have been discussed in Sections 2.1.2.7 and 3.1.2.7 but it is difficult to assess these effects in terms of productivity.

Habitat change per se is not a major threat to large herbivores and predators among mammals or birds. Their behavioral responses to all forms of disturbance could, however, have severe effects on breeding success and loss of range and, therefore, on productivity. The cumulative effects of the proposed project and the other human influences which have preceded it or will follow are essentially certain to cause a decline in productivity of the wolf, barren ground grizzly, wolverine and raptorial birds.

Forest-Tundra and Forest Dominated Ecosystems

Productivity of these ecosystems would be affected in the same manner as in the tundra and with the same consequences to their respective plant and animal components (see Sections 2.1.2.6; 3.1.2.6; 2.1.2.7; and 3.1.2.7). Primary production on the right-of-way would decline in the short term and that portion provided by forest trees for the duration of the pipeline. Production would also be lost for the life of the project on areas occupied by roads, airstrips and other permanent facilities. Recovery rates to normal productivity levels would be more rapid than in the tundra.

The greater plant biomass and summer dryness characteristic of these ecosystems make them susceptible to fires. The burning of mature forests results in increased productivity and greater diversity of plant and animal components. Pipeline ruptures followed by fire in the Forest-Tundra would destroy the lichen ground cover which is the winter forage of caribou. Such fires added to the naturally occurring ones could result in a decline in caribou productivity.

Clearing of closed canopy forest communities for the right-of-way would result in the so-called "edge effect" accompanied by increased productivity. Increased light and greater diversity of herbaceous and shrub types of vegetation produces increased primary production, increased annual biomass, and a wider range of environmental conditions which attract a greater diversity of animals, especially small mammals and song birds. These in turn would attract bird and mammal predators to the right-of-way as a hunting area.

The overall impact of the proposed pipeline on productivity of forest ecosystems would not be large except for the acreage removed from forest production (see Section 3.1.2.6) and the uncertainty of the behavioral responses of birds and mammals characteristic of each ecosystem.

Parkland and Grassland Ecosystem

These ecosystems, largely taken over by grazing and agriculture, occur as remnants of natural communities. The proposed pipeline would further reduce their areas and productivity to the extent of land occupied (Section 3.1.2.7). Recovery of vegetation, except parkland trees, would restore productivity to the right-of-way. Cropland and pastures would be restored to normal production within 2 years.

Ecosystem Interrelationships

Some of the characteristics of ecosystems have been discussed previously (Section 2.1.2.8) and interrelationships and interdependencies illustrated by the concept of the food web. The flow of energy and materials through an ecosystem links all biological components into a unified, balanced system. Environmental change that creates imbalances in the food web pulses through the entire interrelated system.

An ecosystem at any scale is a balanced system requiring only radiant energy from the sun as an external influence which permits all other interrelated functions to take place strictly internally within its boundaries. Such systems are under a variety of controls which if modified produce concomitant change in the system.

Terrestrial ecosystems develop under the major control of climate; land relief (which through exposure and altitude modifies climate); type of soil parent materials; the species of plants and animals available; and time. The equilibrium states achieved by each system require time on the order of thousands of years. Disruptions to these equilibria would require tens, hundreds, or thousands of years depending upon the magnitude of change which, in the extreme case, would preclude recovery.

Among these controls, the proposed project would have no effect upon regional climate or major relief features at the scale of mountains, plateaus and plains. It would have a minor potential of introducing new species to the biota. There would be a moderate potential of displacing certain animals from the affected portion of their range and a minor potential of endangering the survival of a few highly vulnerable species. The long-term cumulative effects of the proposed project, others which are essential to its operation, and still other developments to come, could have major impact on the forced migrations, reduced populations, or even extinction of some vulnerable species.

With respect to the major controls on ecosystems the proposed project would have localized effects on climate, relief, soil materials and biotic components at meso- and micro-scale levels. Relief changes would depend upon earth moving operations and the degree of induced erosion and of deposition off the right-of-way. Microclimates would change with the relief and exposure and any alteration of surface properties, including vegetation and peat layers, affecting the exchange of incoming and outgoing radiation. Vegetation would be altered by erosion, drainage changes and water supply, changed microclimates, fire and other factors. Animal populations would shift with all of the foregoing changes which would affect their food supply and other habitat requirements.

All of these alterations occur in nature and if stability of surfaces could be maintained and there is no extinction of species there would be the potential of return to ecosystem equilibrium following disruption. In time, vegetation would develop in relation to relief, soil parent materials and microclimates; soils would develop in relation to relief, parent materials and vegetation; and microclimates would develop in relation to soils, relief and vegetation. That these restorative changes would occur simultaneously in orderly sequence illustrates the intricacies of the environmental complex. No component of the complex would change without affecting others and it is the total effect that is significant.

The ways in which ecosystems may be perturbed include any quantitative or qualitative changes in any component of the system whether physical, chemical, or biological. Variations in nature are continuous and every system undergoes cyclical and periodic fluctuations which are normal, natural expressions of community dynamics. For example, the rather violent population explosions of the brown lemming on a 4- to 5-year cycle may be accompanied by extreme over-utilization of food plants and the build up of populations of such predators as snowy owls, jaegers, foxes, and weasels. Such events have large impact on the tundra ecosystem but they lie within the limits of the system and are characteristic of it.

Change may entail events which have minor effect or they may be catastrophic and eliminate a specific system or parts of a large system. The impact of an environmental change is a matter of scale and small systems such as an arctic lake with few kinds of organisms, especially among primary producers, may be easily and irretrievably disrupted by chemical pollution. Natural catastrophic change in freshwater lakes on the Arctic Coastal Plain occurs when storm surges pour salt water into them or thawing of permafrost barriers opens drainage ways, empties the basins, and exposes new land surface. In either case one system is destroyed and new systems develop, one a brackish water system and the other a terrestrial one.

Major systems are not readily destroyed but the attrition of long-term cumulative changes complete the destruction, as history demonstrates in all parts of the world. All that is required is effective change inimical to the system, and time. Basically these effective changes, among others, involve the addition of components such as chemicals which are new and deleterious to the system; the addition of materials natural to the system but at excessive rates, such as the overloading of lakes and streams with organic waste or fertilizers; the removal of any element essential to life processes, such as oxygen depletion in lakes; the elimination of biotic components such as lemmings or caribou; or the change of any condition necessary for life processes, such as suitable temperatures.

The kinds of change which may disrupt systems are too numerous for enumeration here but the important point to be made is that they are complex and have no single effect but start chains of reactions which, whether cataclysmic or slow and chronic, have deleterious effects throughout the system. The experimental perturbation of ecosystems and analyses of the chain of consequences have rarely been attempted and only historical observations, knowledge of some relationships, and inference, give insight into the short- or long-term effects of a major project such as the proposed pipeline.

There is no possibility of predicting the total impact of the proposed project on any of the major ecosystems that would be affected. The changes would be generally adverse and perhaps the greatest overall result would be the toll taken in the shrinking number of ecosystems in their natural state. All systems are capable of absorbing some change and recovering, but how much change is not known and it would be prudent to know. In the absence of predictive capacity, it becomes a crucial question whether or not the proposed project would foreclose future options of preserving natural communities at major ecosystem scales.

3.1.2.9 Economic Factors

Principal Economic Activities

The projected new economic activities that could be generated in the study region through approximately 1981-82 by a pipeline project may be subdivided into three groups: primary direct, primary indirect, and secondary activities. These would be in addition to the current activities that would be expected to continue with or without a pipeline project.

Primary Direct

The activities that would be the primary direct result of the proposed pipeline project are those immediately concerned with the construction of a pipeline. These would include, initially, surveys and clearing of a right-of-way, moving of equipment, stockpiling of materials, and construction of support facilities, wharves, staging areas, access roads, and base camps, and would occupy approximately the first year. During the next 2 years construction of the pipeline would take place. Over the succeeding 2-3 years, 36 compressor stations spaced about 50 miles apart would be constructed. Postconstruction clean-up projects would continue during possibly the first 5 years of operation of the proposed line. This cleanup period would provide an easing of the effects of unemployment on the resident population. Instead of operations just ending and numerous laborers becoming unemployed at one time, the cleanup operations will mean a gradual decline in jobs allowing the population to adjust in a more orderly fashion. However, it will also mean that services will have to be provided for a longer period to the non-permanent residents.

Proposed operational centers would be located at Fort Simpson, Norman Wells and Inuvik. Inuvik would continue as an administrative and district office, and the others as only district maintenance offices.

Primary Indirect

The primary indirect activities that might be induced by the proposed project are: gas-field exploration, development, and production, gas-gathering systems and plants, oil exploration, related transportation services, and related equipment supply operations.

Petroleum exploration, development, and production includes: seismic and other survey work; wildcat, development and step-out well drilling; gathering-system construction and operation; gas-field production and processing plant operation; and field service and supply. Gas discoveries and possibilities have been much more promising than oil in the study region, and some of the sub-regions show greater potential than others. Projections of future exploration activity and the more likely sub-regions in which it will be conducted must obviously be based on assumptions about the continuing rate of exploration success, geologic knowledge, and economic and other factors that influence the search for oil and gas. Currently, a considerable degree of success has rewarded exploration programs in the Mackenzie Delta area, but new hydrocarbon finds in the other sub-regions have been minor. Exploration in the Central Mackenzie Sub-region has been chiefly related to extending known reserves in the Norman Wells area, and exploration in the Upper Mackenzie Sub-region was associated largely with the Beaver River-Pointed Mountain gas field that is now in production.

Most of the gas development and production activity over the next decade has been assumed to be concentrated in the Mackenzie Delta and particularly northeast of Inuvik. The assumptions for the region are:

1) Seismic and geologic activity in all sub-regions would decline.

2) The proposed pipeline project would not induce increased exploration, except in the Mackenzie Delta, until the pipeline is completed and operating.

3) Drilling would not increase above present levels in the Central and Upper Mackenzie Sub-regions until such time as the pipeline might be completed.

4) Exploration in the Northeastern Yukon Sub-region would be maintained at no greater than current levels for the next 4 years.

5) Development and production of Mackenzie Delta gas would take place within the next 8 years, but no other sub-region would reach this stage within that period of time.

6) Development, production and transportation of oil from Canada's north would not be expected within the next 8 years.

These assumptions are believed to be reasonable providing that the proposed pipeline would be constructed, and that land claims, environmental standards, and similar problems would be resolved. It should be noted that a single promising hydrocarbon show in any of the sub-regions could greatly alter the forecast assumptions.

Transportation service needs that would be generated by the proposed pipeline construction include increased air support and airstrip construction, expansion of water transport capabilities, construction, extension and improvement of highways, and increased railway freight service.

Equipment supply, warehousing and stockpiling operations, particularly at transportation transfer points, would be required in the construction phases of the proposed pipeline. Possible locations for these activities would be Hay River and Enterprise, Fort Simpson, Norman Wells, Arctic Red River, Fort McPherson and Inuvik.

Secondary

Secondary economic activities are those generated in the service and other sectors as the result of increased spending by persons in the primary employment categories. If the pipeline is built the most significant impact during the construction phase would be chiefly on the secondary facilities in the large centers on the pipeline route such as Inuvik, Fort Simpson, and Aklavik. During the operational phase the impact would be much less and would be felt chiefly in Inuvik and, to a minor extent, in Norman Wells and Fort Simpson. There would be demands for more wholesale and retail trade, transient accommodations, and food services. Some improvement and expansion of communication facilities could be expected. Although the construction period itself will be relatively brief, housing construction in the study region will be stimulated both by need and the increased cash flow, and this in turn would reinforce the demand for lumber and thus stimulate local forestry operations. Local development of gas fuel supply to communities might be expected adjacent to the proposed pipeline. The increased activity, transportation, and population that the proposed pipeline would create might be expected to reinforce the need to enlarge and upgrade local health care facilities.

Employment

Employment effects are used as a proxy for potentially more complex regional economic variables such as income, capital flows, and other monetary effects of major investments such as the proposed pipeline project. It is preferable to estimate net regional income effects of externally financed projects, but, in an economy such as that of northern Canada where substantial elements of new projects represent purchases from nonresident business and industry, the leakage effects preclude accurate direct estimates of income effects within the region.

There are income and expenditure leakage phenomena in the northern economy, with income leakage being the amount of total regional income that accrues to nonresident interests and expenditure leakage being the amount expended by residents for the purchase of goods produced outside the region. An estimate of the portion of income that would be generated from gas developments and become a permanent feature of the regional economy is of particular concern in this study. Employment effects are deemed to provide a reasonably good proxy for this residual regional income.

Employment is divided into three categories for purposes of assessing the projected impact of the proposed pipeline--direct, indirect, and induced.

Direct Gas Pipeline Employment

Employment is expressed in man-year equivalents, which allows more convenient handling of seasonal jobs.

Direct manpower requirements in the construction phase would rise from 265 man-years in the initial year, to a peak of 2,863 man-years in the fourth year, and then drop back to 672 man-years in the seventh year (Table 3.1.2.9-1). This would cover proposed initial preconstruction activities, actual pipeline and compressor station construction between 60° N. latitude and Prudhoe Bay and Richards Island, and compressor station buildup. The proposed pipeline construction in the Yukon and Northwest Territories would be heavily concentrated in the winter months, with compressor station construction proposed throughout the year, and projected stockpiling and other activities would be done in the summer months. The proposed seasonal employment is summarized in Table 3.1.2.9-2, which shows that the average number of men would vary from a low of 340 in the first summer to a peak of 6,770 men in the winter of the third year.

The average skill composition of the temporary labor force that would be required overall is divided into 63.5 percent skilled work force, 16.5 percent semiskilled, and 20.0 percent unskilled. The projected variations in needs for these types of labor that would be anticipated because of the seasonal nature of activities are summarized in Table 3.1.2.9-3.

Employment in the proposed operation and maintenance phases of the pipeline is estimated to rise from about 107 man-years in the third year of the proposed project to a permanent staff that would represent about 240 man-years annually after the sixth year of this project. The projected breakdown would be 14.0 percent in supervisory and management positions, 43.0 percent in skilled labor positions such as pilots, mechanics, welders, electricians, and other technicians, and 43.0 percent in semiskilled jobs including clerks, typists, equipment operators, and maintenance. These would be divided between units in Inuvik, Norman Wells, and Fort Simpson.

Indirect Gas Pipeline Employment

Feasibility and planning studies by the Canadian Arctic Gas Pipeline Company were begun in 1970 and are projected through 1975. An estimated $80 million will have been spent on this, and approximately 10 percent of this amount has been for construction and operation of three northern test facilities, two of which are in Northwest Territories. Some northern labor was used for construction and maintenance tasks, but the money expended was chiefly for design engineering and equipment. Actual northern employment is estimated at 60, 40, and 20 man-years in 1973, 1974, and 1975, respectively. This activity has had and would have little impact on employment within the study region.

Employment opportunities in the field of oil and gas exploration, development, and production would be projected on the basis of assumptions previously outlined. This activity would presumably focus largely (70 percent) in the Mackenzie Delta Sub-region, and would be greatly dependent upon construction of the proposed pipeline. The potential employment is outlined by sub-regions in Table 3.1.2.9-4. This shows that employment might rise gradually from about 760 man-years in 1973 to a peak of about 2,300 man-years in 1979 and drop to approximately 2,000 man-years in 1983, if the proposed pipeline were to be started in 1975.

Transportation system developments would be expected to generate employment in connection with river channel improvements, river barge

Table 3.1.2.9-1 Employment in construction of gas pipeline, northern Canada, 1975-1981 (man years)

Section/Year	1975	1976	1977	1978	1979	1980[1]	1981[2]
Richards Island to Fort Norman	239	824	1,074	681	301	224	224
Fort Norman to 60° N Latitude	26	169	918	1,373	372	224	224
Prudhoe Bay Supply Line via Coastal Route	0	3	149	809	1,000	336	224
TOTAL MAN-YEARS	265	996	2,141	2,863	1,673	784	672

[1] Assumes construction of 4 stations on main line and 3 stations on Prudhoe Bay Supply Line at 1,345 man-months of construction work per station.

[2] Assumes construction of 4 stations on main line and 2 on Prudhoe Lateral.

Source: Compiled by Gemini North Ltd. from Canadian Arctic Gas Study Limited preliminary estimates (April, 1973).

Table 3.1.2.9-2 Concentration of men required during peak working periods

Section	Summer 1975	Winter 1975/76	Summer 1976	Winter 1976/77	Summer 1977	Winter 1977/78	Summer 1978	Winter 1978/79	Summer 1979
Richards Island to Fort Norman	290	1,200	310	2,180	470	1,980	130	410	310
Fort Norman to 60° N Latitude	50	140	130	660	630	4,220	230	580	390
Prudhoe Bay Supply Line Coastal in Canada	0	0	0	30	140	570	390	3,430	50
TOTAL	340	1,340	440	2,870	1,240	6,770	750	4,420	750

Source: Compiled by Gemini North Ltd. from Canadian Arctic Gas Study Limited preliminary estimates (April, 1973).

Note: Method of calculation: Summer - Average number of man-months for July, August, September.
Winter - Average number of man-months for January, February, March.

Table 3.1.2.9-3 Employment in construction of gas pipeline by skill category, northern Canada, 1975-1981 (man years)

Section	1975			1976			1977			1978			1979			1980			1981		
	S[1]	SS[2]	US[3]	S	SS	US	S	SS	US	S	SS	US	S	SS	US	S	SS	US	S	SS	US
Richards Island to Fort Norman	118	52	69	497	141	186	662	193	219	413	116	152	215	42	44	160	31	33	160	31	33
Fort Norman to 60° N Latitude	13	6	7	102	29	38	566	165	187	834	233	306	267	51	54	160	31	33	160	31	33
Prudhoe Bay Supply Line via Coastal Route	0	0	0	2	0	1	92	27	30	491	138	180	716	138	146	241	46	49	160	31	33
SUB-TOTALS	131	58	76	601	170	225	1,320	385	436	1,738	487	638	1,198	231	244	561	108	115	480	93	99
TOTALS	265			996			2,141			2,863			1,673			784			672		

[1] Skilled labour category includes foremen, welders, journeymen, equipment operators, mechanics, skilled tradesmen, teamsters and apprentices to all categories. Apprentices increase from about 2 per cent to 8 per cent of the total pipeline construction work force over the 1975-1979 period.

[2] Semi-skilled labour category includes helpers, rodmen, chainmen, power saw operators, paper latchers, firemen, bullcooks, filers, buffers, spotters.

[3] Unskilled labour category includes common labour, skid hustlers, swampers, axemen, crumbers.

[1,2,3] Skill category distributions over the construction period are determined by averaging the monthly distributions by skill category annually for each year of construction for the entire Canadian section of the pipeline.

Source: Compiled by Gemini North Ltd. from data supplied by Canadian Arctic Gas Study Limited (April 1, 1973).

Table 3.1.2.9-4 Gas-related industry employment in study region, 1973-1983 (man years)

Sub-regions	Year 1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Lower Mackenzie/Delta											
Exploration/Development	330	345	640	1450	1453	1495	1085	805	758	463	623
Production	–	45	75	150	215	385	550	550	620	695	695
Sub-Total	330	390	715	1600	1668	1880	1635	1355	1378	1158	1318
Central Mackenzie											
Exploration/Development	204	191	167	154	142	142	242	242	242	242	242
Production	–	–	–	–	–	–	–	–	–	–	–
Sub-Total	204	191	167	154	142	142	242	242	242	242	242
Upper Mackenzie/Slave											
Exploration/Development	80	80	80	80	80	80	120	120	120	120	120
Production	–	–	–	–	–	–	–	–	–	–	–
Sub-Total	80	80	80	80	80	80	120	120	120	120	120
Northern Yukon											
Exploration/Development	150	150	150	150	150	150	300	300	300	300	300
Production	–	–	–	–	–	–	–	–	–	–	–
Sub-Total	150	150	150	150	150	150	300	300	300	300	300
Total Man-years	764	811	1112	1984	2040	2252	2297	2017	2040	1820	1980

Source: Compiled by Gemini North Ltd.

movements, highway construction and operation, and other transportation-related activity.

A 4-year, $20 million channel improvement program for parts of the Mackenzie River in the Central and Upper Sub-regions has been proposed but not approved by the Federal Department of Public Works. The proposed work would be expected to result in 140 man-years per year of employment, with the labor force recruited from the Hay River area. Presumably this would be in anticipation of increased river travel for the proposed pipeline project.

If the proposed pipeline were constructed, increased river freight, barge assembly and construction, barge crews, and loading and unloading crews could be anticipated. A barge construction program, proposed to be done in Hay River, would require about 70 man-years per year for 2 years, and fleet expansions could generate approximately 225 man-years of seasonal employment plus 150 man-years of year-round employment each year over a 4-year period, in addition to the current barge line employment (see summary in Tables 3.1.2.9-5 and 3.1.2.9-6). The total projected water transport system employment, attributed to the proposed pipeline project and to the assumed level of oil and gas exploration, could rise from 295 man-years in 1973 to a peak of 893 man-years in the second and third years of the proposed project, and then decline to about 295 man-years by the eighth and ninth years.

Highway construction is underway or proposed in and near the study area owing in a considerable degree to current and projected petroleum exploration activities and to projected needs of the proposed pipeline. The Dempster Highway connecting Dawson, Y.T., and Inuvik, N.W.T., via Fort McPherson and Arctic Red River is partly completed. Although the Applicant's studies indicated a 1976 completion date, the construction probably will not be completed until 1978 provided sufficient funds are made available, according to A. B. Yates in October 1975. A highway down the Mackenzie Valley from Fort Simpson to Inuvik is proposed. A recent (1975) program established for the Mackenzie Highway calls for completion to Wrigley by 1978, with no plans for construction north from Wrigley. The Liard Highway is also proposed to connect Fort Nelson, B.C., to Fort Simpson, N.W.T., via Fort Liard; construction has begun. Projected average employment on the Dempster and Mackenzie Highways is estimated at 37.8 seasonally adjusted man-months per mile. Man-year employment figures for these two highways are shown in Table 3.1.2.9-7.

The Great Slave Railway, operated by Canadian National Railways Company, between Edmonton, Alberta, and Hay River, N.W.T., would require about 25 additional full-time employees at Hay River and Enterprise during the second through fifth years of the proposed pipeline construction. Currently the railroad employs about 16 permanent and 3 seasonal employees in Hay River.

Jobs in equipment supply, warehousing, and stockpiling operations would be generated if the proposed pipeline is built. These probably would be in or near Hay River, Enterprise, Fort Simpson, Norman Wells, Arctic Red River, Fort McPherson, and Inuvik. Warehousemen, equipment operators, and watchmen would be needed, and an arbitrary employment projection of 150 man-years annually during the second through fifth years of the proposed project is assumed.

The total indirect employment that might be expected from the proposed pipeline project is summarized in Tables 3.1.2.9-8 and -9. These projections, over an 11-year period, show a rise from approximately 1,300 man-years to a peak of 4,000 man-years in 5 years, and then a decline to

Table 3.1.2.9-5 Water-transport system employment, 1973-1980 (man years)

Elements	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Barge Construction at Hay River[a]	-	70	70	-	-	-	-	-	-	-	-
Channel Improvement Program[b]	-	140	140	140	140	-	-	-	-	-	-
Petroleum Industry Barge Employment[c]	295	295	295	378	378	378	340	316	310	295	295
Pipeline Construction Barge Employment[d]	-	-	-	375	375	375	375	-	-	-	-
Total Man-Years	295	505	505	893	893	753	715	316	310	295	295

[a] Assumes Dominion Bridge Company plans to construct barges at Hay River would precede pipeline construction by two years.

[b] Assumes government approval of D.P.W. program. Work to commence in summer of 1974.

[c] Assumes that employment would grow from 285 currently attributable to petroleum exploration in proportion to increases in tonnage due to gas drilling in the Delta.

[d] Assumes pipeline approval by early 1975 and completion of line to Delta and Prudhoe Bay by 1979.

Source: Compiled by Gemini North Ltd.

Table 3.1.2.9-6 Gas-related water-transport system employment by sub-region, 1973-1983 (man years)

Sub-Region	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Lower Mackenzie/Delta	110	110	110	140	140	140	126	120	120	112	112
Central Mackenzie	22	92	92	96	96	26	23	20	20	20	20
Upper Mackenzie	10	80	80	82	82	12	11	10	10	10	10
Slave	153	223	223	575	575	575	555	166	160	153	153
TOTAL	295	505	505	893	893	753	715	316	310	295	295

Source: Compiled by Gemini North Ltd.

Table 3.1.2.9-7 Labor requirements for all-weather highway construction--Mackenzie and Dempster Highways, 1973-1977 (man years) 1/

Sub-Region	1973	1974	1975	1976	1977
Lower Mackenzie/Delta	93	47	103	56	-
Central Mackenzie	-	-	-	591	591
Upper Mackenzie	63	63	214	214	214
TOTAL MAN-YEARS	156	110	317	861	805

Sources: Compiled by Gemini North Ltd. from interviews with Federal D.P.W., Territorial Government Officers, and analysis of employment content of current highway project elements in the Simpson-Camsell Bend and Arctic-Red-McPherson areas (April 1973).

[1/] As a result of changes in time schedules and cuts in 1975 of funds for the Mackenzie Highway, the data in this table are no longer correct.

Table 3.1.2.9-8 Net indirect employment summary by category, 1973-1983 (man years)

Category	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Feasibility	60	40	20	-	-	-	-	-	-	-	-
Lower Mackenzie/Delta Gas Industry	330	390	715	1600	1668	1880	1635	1355	1378	1158	1318
Central Mackenzie Petroleum Exploration	204	191	167	154	142	142	242	242	242	242	242
Upper Mackenzie Petroleum Exploration	80	80	80	80	80	80	120	120	120	120	120
N.E. Yukon/Eagle Plain Petroleum Exploration	150	150	150	150	150	150	300	300	300	300	300
Water Transport Systems	295	505	505	893	893	753	715	316	310	295	295
Highway Extensions	156	110	317	861	805	-	-	-	-	-	-
Railway Transport	-	-	-	25	25	25	25	-	-	-	-
Equipment Supply	-	-	-	150	150	150	150	-	-	-	-
Total Man-Years	1275	1466	1954	3913	3913	3180	3187	2333	2350	2115	2275

Source: Compiled by Gemini North Ltd.

Table 3.1.2.9-9 Distribution of indirect employment by sub-regions, 1973-1983 (man years) a/

Sub-Region	Year										
	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Lower Mackenzie/ Delta	533	547	928	1871	1883	2095	1811	1475	1498	1270	1430
Central Mackenzie	226	283	259	891	879	218	315	262	262	262	262
Upper Mackenzie	153	223	374	401	401	117	156	130	130	130	130
Slave	153	223	223	600	600	600	580	166	160	153	153
N.E. Yukon	150	150	150	150	150	150	300	300	300	300	300
Not Specified b/	60	40	20	-	-	-	-	-	-	-	-
Total Man-Years	1275	1466	1954	3913	3913	3180	3162	2333	2350	2115	2275

Source: Compiled by Gemini North Ltd.

a/ Equipment supply has been allocated as 50 man-years to the Lower and Central Mackenzie and 25 each to Slave and Upper Mackenzie. All rail employment was assigned to the Slave sub-region. Other sub-regional allocations are based on distributions in previous tables.

b/ Planning and feasibility employment.

2,300 man-years in the last year. This would be a permanent addition to the wage economy in the Northwest and Yukon Territories.

Induced Gas Pipeline Employment

A major problem in deriving induced employment in the Northwest Territories is to make proper allowance for employment income that would be lost to expenditure leakage, which is directly related to the degree of closure in an economic system. This leakage should diminish as the size and degree of self-sufficiency of the region increases.

Employment that would be induced by the proposed pipeline has been estimated at 20 percent of the projected additional direct and indirect employment. The magnitude of induced service employment would be expected to vary appreciably between communities, being highest in the largest and most developed centers and lowest in those least developed.

Total employment that might be generated by the proposed pipeline and related developments is shown (Table 3.1.2.9-10) to rise from a 1973 level of approximately 1,300 man-years to a peak of about 6,400 man-years in 1978, assuming that construction would start in 1975, and dropping back to 2,700 man-years after 1982. The net effect, after peak construction and exploration phases, would be to double the 1973 employment associated with the petroleum industry. The induced employment figures are derived by applying the 20 percent factor only to proposed permanent direct and indirect gas industry employment. Projected construction, exploration and related transport jobs have been assumed to be filled by transient labor.

Induced employment, in man-years and by sub-regions, that could be expected to be generated by permanent employment in the proposed pipeline and gas producing industry is shown in Table 3.1.2.9-11. It is shown that the majority of the projected new employment opportunities, including induced employment, would be in the Lower Mackenzie Delta Sub-region. Total induced employment in all the sub-regions projected over the assumed period would rise from a low of 9 man-years in 1974 to a peak of 187 man-years in 1982 and 1983 (Table 3.1.2.9-10).

Income

An appraisal of the impact of the proposed pipeline project on territorial incomes has been made by the Economic Staff Group of the Northern Economic Development Branch, Department of Indian Affairs and Northern Development, and the MPS Associates, Ltd. (1974). As a basis for the appraisal, the estimated increases in average income were calculated and showed what each potential pipeline worker might receive compared to his income were he to continue his regular work. The income assessment, shown in Table 3.1.2.9-12 compares (a) the average income of Indigene and Other workers in each occupation considered relevant to pipeline employment, based largely on 1970 manpower surveys, with (b) an estimate of pipeline earnings for 1970, based on a typical annual pattern of pipeline industry work, wage rates and fringes paid.

The figures in Table 3.1.2.9-13 show that the projected average increase in income for Indigenes could range from 50 percent to more than double, except in the office assistants and surveyors assistants categories, and for others the increases could range from 10 to as much as 75 percent, except in the surveyors' assistants category. Some of the more extreme differences are, in part at least, attributed to low earnings of Indigenes due to part-time participation in traditional land-related activities, and to the fact that some occupations in the north have been seasonal and subject to erratic demand. It should be noted that in late 1971, average wage rates in the pipeline industry were increased by 8-10 percent. The figures given in Table 3.1.2.9-13 based on 1970 have been revised to allow for a 5 percent annual inflation and are restated in 1973 dollars in Table 3.1.2.9-13.

The estimated gross cash income effect of the proposed direct pipeline employment for 3 profile years is shown in detail in Table 3.1.2.9-14. The estimated average earned income from all sources in Northwest Territories and the potential earnings from proposed pipeline work have been multiplied by a probable estimate of the resident male Indigenes and others who might work on this proposed project, and the estimated gross cash income (before personal taxes) of these individuals is compared with the estimated income they would receive if no pipeline is built. A gross additional personal cash income of about $4.8 million during the year of proposed major construction would result, and would include an approximate 73 percent increase for Indigenes and 27 percent for others. In the proposed post-pipelaying, compressor, and operation facility construction period, about $1.15 million income is projected, 97 percent of which would accrue to Indigenes and 3 percent to others. In the proposed post-construction, capacity-operation profile year a gross increase of $207,000 is estimated, of which 98-99 percent would accrue to Indigenes.

The probable income effect of the direct employment of territorial residents in the proposed pipeline and related transport activities over 20 years, assumed to be 1975-1995, have been projected. On a gross before-tax basis in terms of 1970 values, total income over this period would be nearly $23 million higher (Table 3.1.2.9-15).

A demand is assumed for indirect or secondary labor induced in the public and private sectors as a result of the proposed pipeline project. A projection of average before-tax gross cash incomes of induced labor that might be generated shows an increase of about 33 percent in the government sector and about 80 percent in the private sector. The income effects are summarized in Table 3.1.2.9-16 and it is shown that before-tax gross cash income over the proposed period 1975-1995 would be nearly $5.7 million higher if the pipeline were constructed.

Increased incomes that would be generated by the proposed pipeline project could produce some adverse effects. Increased alcohol abuse in the Yukon and Northwest Territories could result unless offsetting measures are introduced. Increased demand for labor, goods, and services in communities with a limited economic base might increase inflationary pressures in the study region, especially in the high-impact centers. As incomes rise, living costs would also rise for an unknown number of permanent employees who move from a small settlement to a larger center; such increases would be attributed to municipal taxes and to a dependence on commercial food rather than food from the land. Increased incomes could expand the modest number of natives in the middle-income bracket (per capita income was $2,084 in 1973) and create social and economic disparities and tension within the native ethnic groups.

Local Tax Structure and Tax Base

There are four areas in which the territorial governments could realize increased revenues from activities that would be generated by the proposed pipeline; property taxes on the proposed pipeline and associated facilities, grants-in-lieu of personal and corporate income taxes, fuel taxes, and liquor sale revenues. Communities in the city, town, and village categories can levy property taxes, and license and other fees, and hamlets can levy

Table 3.1.2.9-10 Total employment generated by pipeline, gas industry and related developments, 1973-1983 (man years)

Sub-region	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Lower Mackenzie/Delta											
a. Direct[a]	-	-	240	828	1269	1555	1362	634	522	74	74
b. Indirect[b]	533	547	928	1871	1883	2095	1811	1475	1498	1270	1430
c. Induced[c]	-	9	15	30	52	90	122	125	139	154	154
Sub-Total	533	556	1183	2729	3204	3740	3295	2234	2159	1498	1658
Central Mackenzie											
a. Direct	-	-	10	63	408	477	147	93	77	77	77
b. Indirect	226	283	259	891	879	218	315	262	262	262	262
c. Induced	-	-	-	-	4	17	15	19	15	15	15
Sub-Total	226	283	269	954	1291	712	477	374	354	354	354
Upper Mackenzie											
a. Direct	-	-	15	105	571	1053	385	325	313	89	89
b. Indirect	153	223	374	401	401	117	156	130	130	130	130
c. Induced	-	-	-	-	8	15	17	20	18	18	18
Sub-Total	153	223	389	506	980	1185	558	475	461	237	237
Slave											
a. Direct	-	-	-	-	-	-	-	-	-	-	-
b. Indirect	153	223	223	600	600	600	580	166	160	153	153
c. Induced	-	-	-	-	-	-	-	-	-	-	-
Sub-Total	153	223	223	600	600	600	580	166	160	153	153
Northern Yukon											
a. Direct[d]	-	-	-	-	-	-	-	-	-	-	-
b. Indirect	150	150	150	150	150	150	300	300	300	300	300
c. Induced	-	-	-	-	-	-	-	-	-	-	-
Sub-Total	150	150	150	150	150	150	300	300	300	300	300
Not Specified[e]											
Indirect	60	40	20	-	-	-	-	-	-	-	-
All Sub-regions											
a. Direct	-	-	265	996	2248	3085	1894	1052	912	240	240
c. Indirect	1275	1466	1954	3913	3913	3180	3162	2333	2350	2115	2275
c. Induced	-	9	15	30	64	122	154	164	172	187	187
Total	1275	1475	2234	4939	6225	6387	5210	3549	3434	2542	2702

Table 3.1.2.9-10. Notes.

Source: Compiled by Gemini North Ltd.

[a] Direct employment includes man-years of employment in pipeline construction and operations in the Lower Mackenzie, Delta and Northern Yukon combined. Annual employment after 1981 is estimated at 240 man-years for pipeline operations and maintenance.

[b] Indirect employment includes man-years of employment in exploration and development drilling, construction and operation of gas processing plants, gas field operations, construction of highways, barge operation attributable to petroleum, related transport employment (barge assembly, rail operation, equipment supply and warehousing), and exploratory drilling in other areas in the study region.

[c] Induced employment includes jobs generated in the service sector in communities. The estimate is derived by summing the permanent direct and indirect base employment generated by gas industry development, and applying a multiple of 20 percent to net base employment. The multiplier was not applied to construction exploration, and related transport jobs since the work force used was assumed to be transient.

[d] Pipeline construction employment in the Northern Yukon was assigned to the Lower Mackenzie/Delta sub-region.

[e] Includes employment in feasibility and planning.

Table 3.1.2.9-11 Permanent employment generated by pipeline and gas-producing industry, 1974-1983 (man years)

Sub-regions	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Lower Mackenzie/Delta										
Pipeline and Gas Industry	45	75	150	261	451	611	624	694	769	769
Induced	9	15	30	52	90	122	125	139	154	154
Sub-Total	54	90	180	313	541	733	749	833	923	923
Central Mackenzie										
Pipeline and Gas Industry	–	–	–	22	84	73	93	77	77	77
Induced	–	–	–	4	17	15	19	15	15	15
Sub-Total	–	–	–	26	101	88	112	92	92	92
Upper Mackenzie										
Pipeline and Gas Industry	–	–	–	39	73	87	101	89	89	89
Induced	–	–	–	8	15	17	20	18	18	18
Sub-Total	–	–	–	47	88	104	121	107	107	107
All Sub-regions Total	54	90	180	386	730	925	982	1032	1122	1122

Source: Compiled by Gemini North Ltd.

Table 3.1.2.9-12 Estimated increase in annual earnings of Northwest Territories residents through pipeline employment by occupation (per work; basis, 1970 values)

	Estimate of Average Earned Income From All Work In N.W.T. in 1970		Potential Earnings From Pipeline Basis 1970 Levels	Potential Increase In Male Earnings Through Pipeline Employment			
				Indigene		Other	
Occupation Name	Indigene	Other		$	% Increase	$	% Increase
Administrative Trainee	$ 5,198	$ 8,942	$ 9,888	+ 4,690	90.2	+ 946	10.6
Carpenter	7,968	8,417	12,415	+ 4,447	55.8	+ 3,998	47.5
Carpenters Apprentice	3,395	5,818	10,210	+ 6,815	200.7	+ 4,392	75.5
Cooks Helpers	2,060	4,400	6,462	+ 4,402	213.7	+ 2,062	46.9
Drivers (Truck & Bus)	5,190	6,269	11,261	+ 6,071	117.0	+ 4,492	79.6
Electricians Apprentice	7,333	8,131	11,040	+ 3,707	50.6	+ 2,909	35.8
Engineers (Prof.)	-	6,747	24,000	-	-	-	-
Foreman	5,956	8,579	12,873	+ 6,917	116.1	+ 4,294	50.1
Labour	2,650	4,874	7,259	+ 4,609	173.9	+ 2,385	48.9
Mechanics	3,492	7,187	10,583	+ 7,091	203.6	+ 3,396	47.3
Mechanics Helpers	4,500	6,940	8,395	+ 3,895	86.6	+ 1,455	21.0
Millwright	3,700	7,887	11,787	+ 8,087	218.6	+ 3,900	49.5
Oilers	-	-	8,395	-	-	-	-
Office Assistants	7,481	6,686	7,530	+ 49	0.7	+ 844	12.6
Plumbers Apprentice	1,454	6,333	10,719	+ 9,265	637.2	+ 4,386	69.3
Principal Operators	5,985	8,433	10,583	+ 4,597	76.8	+ 2,150	25.5
Surveyors Asst.	7,800	8,898	7,259	- 541	- 6.9	- 1,639	- 18.4
Technicians	-	9,250	9,250	-	-	-	-
Welders	-	7,846	10,583	-	-	+ 2,737	34.9
Welders Helpers	3,856	6,175	8,293	+ 4,437	115.7	+ 2,118	34.3

Table 3.1.2.9-13 Estimated increase in annual earnings of northern residents through pipeline employment by occupation (1973 dollars)

	Estimate of Average Earned Income From All Work in 1973		Potential Earnings From Pipeline 1973 Values	Potential Increase In Earnings Through Pipeline Employment			
				Indigene		Other	
Occupation Type	Indigene	Other		$	% Increase	$	% Increase
Administrative Trainee	6,019	10,355	11,450	+ 5,431	90.2	+ 1,095	10.6
Carpenter	9,227	9,747	14,377	+ 5,150	55.8	+ 4,630	47.5
Carpenters Apprentice	3,931	6,737	11,823	+ 7,892	200.7	+ 5,086	75.5
Cooks Helpers	2,385	5,095	7,483	+ 5,098	213.7	+ 2,388	46.9
Drivers (Truck & Bus)	6,010	7,260	13,040	+ 7,030	117.0	+ 5,202	79.6
Electricians Apprentice	8,492	9,416	12,784	+ 4,293	50.6	+ 3,369	35.8
Engineers (Prof.)	-	7,813	27,792	-	-	-	-
Foreman	6,897	9,934	14,907	+ 8,010	116.1	+ 4,972	50.1
Labour	3,069	5,644	8,406	+ 5,337	173.9	+ 2,762	48.9
Mechanics	4,044	8.323	-12,255	+ 8,211	203.6	+ 3,933	47.3
Mechanics Helpers	5,211	8,037	9,721	+ 4,510	86.6	+ 1,685	21.0
Millwright	4,285	9,133	13,649	+ 9,365	218.6	+ 4,516	49.5
Oilers	-	-	9,721	-	-	-	-
Office Assistants	8,663	7,742	8,720	+ 57	0.7	+ 977	12.6
Plumbers Apprentice	1,684	7,334	12,413	+10,729	637.2	+ 5,079	69.3
Principal Operators	6,931	9,765	12,255	+ 5,323	76.8	+ 2,490	25.5
Surveyors Asst.	9,032	10,304	8,406	- 626	- 6.9	-1,898	-18.4
Technicians	-	10,712	10,712	-	-	-	-
Welders	-	9,086	12,255	-	-	+ 3,169	34.9
Welders Helpers	4,465	7,151	9,603	+ 5,138	115.7	+ 2,453	34.3

Notes:

1. Adapted from Table 23, p. 106, Vol. 1, MPS Impact Study. Figures in the MPS Table 23 were given in terms of 1970 dollars. The above table inflates the MPS figures to 1973 dollars by using an annual inflation factor of 5% (compounded annually). It is realized that the earnings for the 20 classes of labour will probably increase at differing rates. However, it was felt that an average annual increase of 5% (approximately the annual rate of price inflation in the Canadian economy 1970-73) was much less troublesome than the multiple assumptions required to project nominal prices advancing at a variety of hypothetical rates (i.e., a different rate for each of the 20 labour classes).

2. The MPS results in their Table 23 (see note 1 above) referred only to N.W.T. earnings with and without a pipeline. In this analysis it is assumed that average Yukon earnings for a given occupational class without a pipeline are the same as they are in the N.W.T.

Table 3.1.2.9-14 Estimated gross cash income effect of probable territorial employment on a gas pipeline during profile years of the three major periods of activity (thousands of dollars; basis, 1970 values)

	Period of Major Pipeline Construction "Profile Year" - 1977/78			Post Pipelaying Compressor And Operating Facility Construction Period "Profile Year" - 1981			Post-Construction Period Of Capacity Operation "Profile Year" - 1985		
	Indigene	Other	Total	Indigene		Total	Indigene	Other	Total
(A) Gross Cash Income of Direct and Related Pipeline Labour									
Wages and Salaries	$ 5,593	$4,609	$10,202	$ 1,754	$ 114	$1,868	$ 384	$ 38	$ 422
Employer Payroll Contributions	194	142	336	60	3	63	13	1	14
Unemployment Insurance Benefits	336	246	582	105	6	111	22	2	24
Total	6,123	4,997	11,120	1,919	123	2,042	419	41	460
(B) Gross Cash Income of Pipeline and Related Labour Assuming No Pipeline									
Earned Income from All Sources	2,378	3,372	5,750	729	85	814	195	35	230
Estimated Fringe Benefits Other Direct Receipts	238	337	575	73	8	81	20	3	23
Total	2,616	3,709	6,325	802	93	895	215	39	253
(C) Increase in Gross Cash Income Resulting from Pipeline Employment									
Difference in Earned Income	3,215	1,237	4,452	1,025	29	1,054	189	3	192
Difference in Fringes & Other Receipts	292	51	343	92	1	93	15	-	15
Total	3,507	1,288	4,795	1,117	30	1,147	204	3	207
-Other Income Related Costs Resulting from Pipeline Employment									
Imputed Cost of Room and Board	2,305	1,684	3,989	717	38	755	151	14	165
Clothing Allowances	67	49	116	21	1	22	4	-	4
Cost of Travel	1,075	786	1,861	334	17	351	71	6	77
Total	3,447	2,519	5,966	1,072	56	1,128	226	20	246

Table 3.1.2.9-15 Income effect of direct territorial pipeline employment (thousands of dollars; basis, 1970 values)

Estimated Gross Earned Income	Pipelaying Period	Compressor Construction	Capacity Operation	Total
	(1975-79)	(1980-83)	(1984-95)	
Indigenes				
- On pipeline	$19,545	$8,707	$5,028	$33,280
- If no pipeline	8,350	3,639	2,580	14,569
Increase	11,194	5,068	2,448	18,710
Others				
- On pipeline	15,950	558	492	17,000
- If no pipeline	11,839	422	468	12,729
Increase	4,111	136	36	4,283
Combined Increase	$15,305	$5,204	$2,484	$22,993

Table 3.1.2.9-16 Income effect of indirect territorial pipeline employment (thousands of dollars; basis, 1970 values)

	Pipelaying Period	Compressor Construction	Capacity Operation	Total
Estimated Gross Earned Income	(1975-79)	(1980-83)	(1984-95)	
Private Sector				
-With a pipeline	$4,750	$1,045	$1,140	$6,935
-No pipeline	2,600	572	624	3,796
Increase	2,150	473	516	3,139
Government				
-With a pipeline	6,630	1,530	1,836	9,996
-No pipeline	4,940	1,140	1,368	7,448
Increase	1,690	390	468	2,548
Combined Increase	$3,840	$ 863	$ 984	$5,687

license and other fees, and thus they would probably obtain some additional revenue as a result of proposed pipeline activities.

Both the Yukon Territory and N.W.T. (Northwest Territories) would realize revenues from real property taxes on the proposed pipeline itself, on the associated installations, and on any buildings or other real property the pipeline company might construct or acquire for its use. The amount of taxes collected would depend upon the assessment and mill levies and these have not been established.

One attempt to approximate the possible tax revenues was based on extending present local ordinances and tax rates for the entire life of the proposed pipeline. This shows that after projected capacity is reached, the two territories would receive about $1.8 million per year in taxes. Assuming that gas were to start flowing in 1979, reach capacity in 1984, and continue through 1995, a total revenue of about $28 million (two-thirds to N.W.T. and one-third to Yukon Territory) would accrue.

Another projection of property tax revenue from the proposed pipeline and associated installations is summarized in Table 3.1.2.9-17. Taxation ordinances (1972) for the two territories indicate initial assessment values of $103,200 per mile for 48-inch pipe in N.W.T. and $141,290 per mile in Yukon Territory. If $940 million is used as the total value of the associated installations and prorated on a mileage basis, values of $320.4 million for N.W.T. and $57.3 million for Yukon Territory are obtained. Using the 1967 Alberta Assessment Manual as a guide, initial assessments of $59.9 million for N.W.T. and $10.7 million for Yukon Territory are derived. Both values are subject to reevaluation every 6 years. Basic rates (1972) are 15 mills in N.W.T. and 26 mills in Yukon Territory, except in municipal tax areas (Whitehorse, Yellowknife, etc.) where mill levies are considerably higher.

It is estimated that buildings valued at about $20.6 million will be needed to service construction and operation of the proposed pipeline. Initial assessment values in the N.W.T. may be approximated by 35 percent of construction cost or $7.2 million. Building requirements in Yukon Territory would be negligible. A projection, based on an average mill rate of 50, would yield annual tax revenues decreasing from $0.36 to $0.23 million (Table 3.1.2.9-18).

Territorial fuel taxes, based on current rates, would be expected to yield approximately $3,533,225 in total revenue during the construction phase of the proposed pipeline (Table 3.1.2.9-19).

An estimate of increased revenues from sales of alcoholic beverages that might be generated by the proposed pipeline project would be governed by as yet undecided alcohol consumption regulations. It seems likely that the impact on territorial liquor revenues might be small because of a desire to minimize alcohol abuse problems in construction camps and in local communities.

During the proposed period of 1975-95 a net increase of approximately $5 million in federal receipts from personal income taxes, at current rates, would be expected to result from direct employment. Indirect employment would be expected to result in a net gain from income tax of about $1.3 million.

Economic Trends and Development

There would be a problem to maintain skilled and semi-skilled wage employment throughout the region at the levels that would be developed during the proposed peak construction years if the pipeline were built. It has been projected that roughly 25,000 man-years might be required over a proposed 8-year construction period, but less than 4,000 man-years might be needed over the following 17-year operations period. Secondary employment would be expected to follow a similar peak and drop-off pattern.

It was estimated by the Northern Planning Group of the Canadian government that the proposed construction and operation of a 48-inch gas pipeline from the Alaska-Yukon border to the N.W.T.-Alberta border over the projected period of 1975-95 would cost about $1.4 billion and $2.0 billion for all Canadian segments. This estimate is based upon a system cost of $5.0 billion. On February 14, 1975, the Applicant raised its estimate of system cost to $6.2 billion. It is likely that not more than 12 percent of the money will be expended within the northern territories for procurement of materials, services, and labor, and only about $2 million of this would be used to purchase locally produced materials. After all proposed construction is finished and the proposed line goes into full operation, the demand for local labor would be small, up to 200 jobs versus over 2,000 at the peak of construction.

Uncertainties about the extent and locations of possible future petroleum and mineral discoveries and developments that might occur along, or be stimulated by, the proposed pipeline preclude valid estimates of economic impact from these sources. It is, however, reasonable to assume that, if the pipeline were built, continuing petroleum exploration activity would be generated in the Mackenzie Delta Sub-region.

The overall future economic impact of the proposed pipeline on the communities would be largely limited to Inuvik, Norman Wells and Fort Simpson. The impact on other communities would be minimal, as workers would be quartered in isolated, self-contained camps, and it is estimated that at the proposed peak of construction only about 650 workers would be living outside of camps and this would decline to about 200 in the post-construction period.

If the pipeline were completed, increased revenues to the Federal, territorial and local governments would be expected. Presumably these funds would aid the governmental units in developing the services and facilities for which they are responsible.

3.1.2.10 Sociological Factors

Population

Evaluations of future migration in and out of the region are very difficult to make; the net result of migration will depend upon many factors, including new economic developments, attitudes of the younger people who are in, or about to become members of, the working force, and the availability of land after settlement of Native claims. A projection of the working age population in 1981 that includes the permanent additional migrant workers for all gas-related jobs shows a total of 22,976, of which 12,163 are males. A comparison of the three projections for 1981 is given in Table 3.1.2.10-1.

The extent to which the proposed pipeline and related developments maximize the participation of Native northerners in employment opportunities will reflect the degree to which employment opportunities are compatible with the inherent characteristics of the northern Native labor force. These characteristics are particularly the nature, location, and duration of employment. For example, it is unreasonable to expect a Native northerner

Table 3.1.2.9-17 Territorial taxes--pipeline and ancillary installations

Yukon Territory

Period	Total Assessment[1] ($ millions)	Current Mill Rate	Annual Revenues[2] ($ millions)	Mill Rate	Annual Revenues ($ millions)
1978 - 83	32.6	.026	0.85	.030	0.98
1984 - 89	23.8	.026	0.62	.030	0.71
1990 - 95	17.6	.026	0.46	.030	0.53
1996 - 99	12.7	.026	0.33	.030	0.38

Northwest Territories

Period	Total Assessment[1] ($ millions)	Current Mill Rate	Annual Revenues[2] ($ millions)	Mill Rate	Annual Revenues ($ millions)
1978 - 83	152.8	.015	2.29	.030	4.58
1984 - 89	111.5	.015	1.67	.030	3.34
1990 - 95	82.5	.015	1.24	.030	2.48
1996 - 99	59.6	.015	0.89	.030	1.78

Table 3.1.2.9-17. Notes.

1. Total assessment for the Yukon computed at 155 miles of pipe at $141,290 per mile plus $10.7 million for the ancillary installations, and for the N.W.T. 900 miles of pipe at $103,200 per mile plus $59.9 million for the ancillary installations.

2. Assuming the pipe is to be allowed to depreciate over 20 years, the Alberta Assessment Manual calls for assessments of 100%, 73%, 54% and 39% of the initial assessed value to be levied for successive six year periods. The Assessment schedule for the ancillary installations depends on a large number of factors, and it is not possible to determine the assessment schedule without a detailed breakdown of the size and type composition of each installation. The approach taken here is to assign these facilities the same schedule as the pipe and lump these two components together as in the above table.

Table 3.1.2.9-18 Northwest Territories property tax--pipeline buildings

Period	Assessed Value[1] ($ millions)	Mill Rate[2]	Annual Tax Revenues
1976-81	7.2	0.050	0.36
1982-87	6.4	0.050	0.32
1988-93	5.5	0.050	0.28
1994-99	4.6	0.050	0.23

Notes

1. The Alberta Assessment Manual calls for a depreciation rate of 2% per year on a straight line basis for tax purposes, with the depreciation being computed on the basis of successive six year periods.

2. Some representative 1972 mill rates were: Inuvik 42 mills, Fort Simpson 42.4 mills, and Norman Wells 46.5 mills.

Table 3.1.2.9-19 Territorial fuel tax revenues expected during construction of the proposed pipeline

	N. W. T.		YUKON	
Type of Fuel	Thousands of Gallons	Tax Revenues	Thousands of Gallons	Tax Revenues
Diesel	13,175	$1,976,250	2,325	$325,500
Aviation Fuel	2,635	65,875	460	9,300
Gasoline	5,270	737,800	930	130,200
Heating Fuels	5,270	158,100	930	130,200
Totals	26,350	$2,938,025	4,650	$595,200

Table 3.1.2.10-1 Total and male working age population in the study region, 1971 and 1981

		Without Major Developments		With Gas Development
	1971	1981 (Low)[a]	1981 (Normal)[b]	1981[c]
Male Working Age Population	7,554	9,651	11,131	12,163
Total Working Age Population	13,549	18,557	20,938	22,976

[a] Cohort adjustment method.

[b] Estimated from working age population ratios applied to the total projected population.

[c] Normal projection plus permanent in-migration for all gas related jobs.

to move his family to Inuvik to gain permanent wage employment if conditions there encourage alcohol abuse, family-unit breakdown, and related social problems. Also, some Native workers may be unwilling to move to predominantly white towns, or to assume fulltime wage employment that would preclude pursuit of part-time hunting, fishing and trapping employment.

Community Structure

Housing

If the proposed pipeline were built, about 4,600 units (an additional 1,100) would be needed by 1983 to accommodate the natural growth plus that generated by the proposed project. Of the 1,100 units that would be required if the proposed pipeline is built, about 240 would be for pipeline employees and families and 860 for the indirect and induced population that would be generated. The major area of this impact would be the Lower Mackenzie Delta Subregion. These projections do not include housing replacements to cover losses due to fire, flood, etc.; probably this loss amounts to 3 percent per year. The details of new housing projections are shown in Table 3.1.2.10-2.

Studies indicate that adequate housing is a prime factor in attracting northerners, white or Native, to employment opportunities and retaining them on the job. It is also known that many Natives prefer to remain in their home communities and rotate to jobs. In planning for future housing, careful attention should be directed to these factors, as one cannot now predict accurately how many northerners would be willing to move to centers and how many Natives would be likely to remain in their settlements and take only part-time employment.

Services

Service activities related to the communities can be broadly subdivided into communications, utilities, wholesale and retail trade, finance, community services, personal services, service for businesses, tourist service, contracting and building, and government. Transportation on a regional scale is in some degree related to all of these activities.

Impact of the proposed pipeline project would be felt most by businesses in the service industries. Most service activities are not well developed in the study region because it has been difficult for northerners to open their own businesses, owing to shortages of stable and qualified labor, high transportation costs, seasonal nature of many businesses, and inadequate opportunities to bid for contracts tendered by southern firms. Many of the services now require upgrading or expansion to keep pace with the normal population growth and social needs, and if the proposed pipeline were built, these needs would be greatly augmented.

Communications

If the proposed pipeline were built, an additional communication network would be needed for pipeline induced traffic. It could tie in with the existing system and result in further upgrading of the entire system.

Table 3.1.2.10-2 Projection of population and new housing requirements, by sub-region, 1971-1983

Sub-Region Item	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Lower Mackenzie/Delta													
Without Gas Development													
(Population[a]	5,472	5,706	5,947	6,188	6,430	6,672	6,913	7,160	7,405	7,649	7,899	8,145	8,389
(Required dwelling (starts/year[b]	78	80	80	81	81	80	82	82	81	83	82	81	
(Cumulative required (dwelling starts	78	158	238	319	400	480	562	644	725	808	890	971	
Due to Gas Development													
(Required dwelling (starts/year[c]	–	–	54	36	90	133	228	192	16	84	90	–	
Grand Total cum. required dwelling starts[d]	78	158	292	409	580	793	1,103	1,377	1,474	1,641	1,813	1,894	
Central Mackenzie													
Without Gas Development													
(Population[a]	1,499	1,563	1,629	1,695	1,761	1,828	1,894	1,961	2,029	2,095	2,164	2,231	2,298
(Required dwelling starts/year[b]	21	22	22	22	22	22	22	23	22	23	22	22	
(Cumulative required (dwelling starts	21	43	65	87	109	131	153	176	198	221	243	265	
Due to Gas Development													
(Extra dwelling (starts per year[c]	–	–	–	–	–	26	75	(13)[e]	24	(20)	–	–	
Grand Total cum. required dwelling starts[d]	21	43	65	87	109	157	254	264	310	313	335	357	

Table 3.1.2.10-2 Continued

Sub-Region Item	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Upper Mackenzie													
Without Gas Development													
(Population[a]	1,602	1,671	1,741	1,812	1,883	1,953	2,024	2,096	2,168	2,239	2,312	2,385	2,456
(Required dwelling (starts/year[b]	23	23	24	24	23	24	24	24	24	24	24	24	
(Cumulative required (dwelling starts	23	46	70	94	117	141	165	189	213	237	261	285	
Due to Gas Development													
(Extra dwelling (starts/year[c]	-	-	-	-	-	47	41	16	17	(14)	-	-	
Grand Total cum. required dwelling starts[d]	23	46	70	94	117	188	253	293	334	344	368	392	
Slave													
Without Gas Development													
(Population[a]	14,873	15,510	16,163	16,821	17,477	18,135	18,789	19,460	20,129	20,792	21,468	22,139	22,802
(Required dwelling (starts/year[b]	212	218	219	219	219	218	224	223	221	225	224	221	
(Cumulative required (dwelling starts[d]	212	430	649	868	1,087	1,305	1,529	1,752	1,973	2,198	2,422	2,643	
Due to Gas Development													
(Extra dwelling (starts/year[c]	-	-	-	-	-	-	nil	nil	nil	nil	nil		
Grand Total cum. required dwelling starts	212	430	649	868	1,087	1,305	1,529	1,752	1,973	2,198	2,422	2,643	

Table 3.1.2.10-2 Continued

Sub Region Item	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Total Region													
Without Gas Development													
(Population[a]	23,446	24,450	25,480	26,516	27,551	28,588	29,620	30,677	31,731	32,775	33,843	34,900	35,945
(Required dwelling (starts/year[b]	334	343	345	346	345	344	352	352	348	355	352	348	
(Cumulative required (dwelling starts	334	677	1,022	1,368	1,713	2,057	2,409	2,761	3,109	3,464	3,816	4,164	
Due to Gas Development (Extra dwelling (starts/year[c]	-	-	54	36	90	206	344	195	57	50	90	-	
Grand Total Cumulative required dwelling starts[d]	334	677	1,076	1,458	1,893	2,443	3,139	3,686	4,091	4,496	4,938	5,286	

Source: Compiled by Gemini North Ltd.

Table 3.1.2.10-2 Notes

[a] Source: Table 3.7 of Volume II, Chapter Three, Gemini North Ltd., 1974. Excludes Northern Yukon.

[b] Calculated by change in population from year to year divided by 3.0 persons per household. Household occupancy has been declining throughout Canada over the past 10 years. Based on the number of houses built between 1961, 1966, and 1971, and on the increase in population between these years, the marginal occupancy per household for Canada was 2.8 persons for 1961 - 1966, 2.2 for 1961 - 1971 and 1.8 for 1966 - 1971. For the Yukon and the N.W.T. combined the occupancy has been declining from 5.9 for 1961 - 1966, to 3.3 for 1961 - 1971 and to 2.7 for 1966 - 1971. For the 1966 - 1971 period, the marginal occupancy was 3.0 in Fort Smith, 2.6 in Hay River and 3.3 in Yellowknife. The projection assumes that units required in any year are built the preceding year. Source: Compiled by Gemini North Ltd. from Government of Canada, Statistics Canada, *1971 Census of Canada*, Vol. II, Part 1, *Household by Size* (Ottawa: Statistics Canada, May 1973), Catalogue 93 - 702, p. 1-1.

[c] Assumes that demand is equal to number of jobs resulting from gas developments, including service industry jobs.

[d] Includes all housing *with* gas development.

[e] Figures in parenthesis indicate surplus housing.

Utilities

If the proposed pipeline is constructed, there would be additional critical needs for utility services, especially water, sewerage, and garbage disposal.

Wholesale and Retail Trade

These businesses are expected to expand with the population, and if the proposed pipeline project is undertaken, the greatest expansion would be expected in the Mackenzie Delta Subregion. Expansion sectors would include local transportation, service stations, repair shops, consumer-oriented stores, and entertainment.

Finance

Insurance, real estate, and banking facilities would be expected to expand to a limited extent with population, chiefly in the larger centers such as Inuvik, Norman Wells, Fort Simpson, Hay River, and Yellowknife. Banking would continue to be controlled from the Provinces, and fly-in banking service would be supplied to smaller communities and camps. Real estate is generally limited to transactions within community limits, as all other lands are Crown lands which can only be purchased if the Applicant is able to meet Federal requirements pertaining to the specific site. The insurance business probably would grow faster than the other financial businesses. The proposed pipeline project would be expected to be a definite stimulant to these sectors of business.

Community Services

This category includes educational facilities, hotels, libraries, day-care centers, health and hospital facilities, religous centers, and recreational facilities. Some expansion of these facilities with a normal increase in population would be needed, and currently day-care and recreational facilities are those in most critically short supply. The proposed pipeline project would create additional needs for schools, vocational centers, and health facilities, particularly in the main centers. The need for hostels would decrease as higher grades of school are established in the small communities.

Personal Services

This category includes such establishments as barber and beauty shops, laundries, cleaners, shoe repair shops, guiding, automobile rental, funeral services, etc. These services are rather minimal throughout the study region, being concentrated in a few large centers, and they are likely to expand only slightly with a normal increase in population. If the proposed pipeline were built, increased demand for such services would be generated, but probably would result in only a small growth of such businesses. In the case of many of these smaller establishments, the population threshold for profitable operation has not yet been reached, and a second similar outlet could not be justified.

Services for Businesses

These services include lawyers, engineers, consultants, accountants, employment agencies, advertising services, security services, etc. Most of these facilities are located in the major communities but serve a clientele over the entire region. A small increase would be expected with an increase in population and modern developments. The proposed pipeline project would be expected to generate a modest increase in demand for these businesses, which would continue to be headquartered in the large centers.

Tourist Services

These services include primarily restaurants, hunting and fishing lodges, hotels, and beverage rooms. Currently none are present in the small and more remote communities of Old Crow, Arctic Red River, Wrigley, Fort Liard, Nahanni Butte, and Fort Rae. Tourists constitute only 15 percent of the clientele at present, the major part being government employees, businessmen, and working crews. These accommodations are, and would continue to be, in high demand on a year-round basis in the main communities with normal population growth. If the proposed pipeline were built, these facilities would likely be operating at full capacity during and after the projected construction period.

Contracting and Building

This group includes highway, dock, and airfield construction, and commercial and private building construction. Normal growth and needs for modernization of facilities would generate considerable activity and expansion in these construction fields over the next 10 years. Projected activities that would be related to the proposed pipeline would materially augment demand for construction services.

Government

This group includes the branches of Federal, Territorial and municipal government involved with education, welfare, health, law enforcement, and economic and local government development. This sector would be expected to increase with the normal level of population and economic growth. Projected activities related directly and indirectly to the proposed pipeline would no doubt generate significantly larger expansion in the fields of government responsibility.

Solid Waste Disposal

Since the capacity of the existing waste disposal facilities along the proposed route is quite limited, it will be necessary for the Applicant to handle the disposal himself.

Combustible materials will be burned in incinerator units. The incinerators will have a high temperature two-stage burner to allow efficient oxidation of the waste to reduce air emission. The residue of the incinerators will be combined with non-combustible wastes and buried in sites clear of drainage into streams and lakes. In permafrost areas, burning is to be controlled to avoid degradation of the permafrost. Burning along the ditch line or on "fire-sleds" are possible solutions.

Cleared timber and brush will mostly be burned since very little is merchantable (Grainge, et al., 1973). That burning would be done along the right-of-way or on "fire-sleds" in permafrost regions. Such burning should be done during periods of low fire hazard. Stumps will be added to the other material placed in burial sites. Once the burial site is filled it would be covered with 24 inches of soil.

In order to eliminate potential impacts on the environment, it might seem better to remove all solid waste to inhabited areas. However, the environmental degradation associated with trucking out waste may be greater than that associated with a properly operated burial site (Grainge, et al., 1973). There is some question about proper use. The harshness of the environment makes it easier to justify the convenient dumping of unnecessary materials, particularly light weight litter which can be picked up by the wind and carried offsite beyond the range of normal inspection procedures. The degradation of litter would be quite slow, resulting in a widespread long time esthetic impact.

Experience with the Trans-Alaska Pipeline System, presently being constructed, indicates that no significant impacts with solid waste disposal have been encountered. Contributory to this is the importance assigned to cleanup and waste control by regulatory agencies.

Attitudes of the Residents

The current and future attitudes of the Territorial residents, particularly the Natives and Metis, might be a potent sociological force relative to projected activities connected with the proposed pipeline project. The Natives are assuming a much more active role, through the legislative process and through several regional ethnic interest groups, in determining the course of Territorial affairs. As previously mentioned, there are many differences of opinions between individuals and groups about their lifestyle and future development, and long standing tensions and resentments between the ethnic groups appear to be surfacing.

One of the constraints in the Canadian Government guidelines for northern pipelines (Department of Indian Affairs and Northern Development, 1972) is that: "Any certificate issued will be strictly conditioned in respect of ... the protection of the rights of northern residents, ... ". Furthermore, the stated government policy is that any decisions made concerning northern pipelines will be without prejudice to Indian land claims and treaty rights.

The extent to which land claim settlements and other legal prerogatives of local residents may determine the granting of the proposed pipeline construction permit is not clear. The attitude of the local residents, as interpreted from limited and subjective surveys, seems to range from full acceptance to complete rejection of the proposed pipeline project.

3.1.2.11 Land Use

The construction phase of the proposed pipeline project would entail the exclusive dedication of 43,060 acres for right-of-way and ancillary installations (Table 1.1.2.4-1) (all totals have been rounded to the nearest acre in this discussion) and the area of more than 100 pits from which about 30 million cubic yards of borrow would be removed. Construction camp sites not on land to be used for ancillary installations to be built during a later part of the construction phase (section 2.1.2.3) would require temporary dedication. The area needed for borrow pits is estimated to be

1,433 acres. All construction camps would be temporary and most would be on land included in the total 43,060 acres previously mentioned. This total is made up of 35,132 acres of right-of-way, 1,808 acres for compressor stations, 2,780 acres for airfields, 1,011 acres of roads, and the remainder (896 acres) for communication towers, wharves, meter stations, and other miscellaneous installations (Table 1.1.2.4-1).

During the operation phase of the project most ancillary installations other than wharves, enough borrow pits to meet maintenance needs that could be determined only after construction had been completed, and part of the right-of-way would not be available for other surface uses. Deep mining, however, would generally not be precluded. For the life of the project, surface mining would be impossible in any part of the project area except abandoned borrow pits. Right-of-way between compressor stations would generally be available for surface uses such as agriculture as soon as construction is completed. As the right-of-way would have to remain clear of major obstacles for the life of the project, forestry and urban development would be precluded.

The only permanent effects the project would have on land use would be the consumptive use of natural gas from fields that fed the pipeline and the consumptive use of borrow, some of which might conceivably be reclaimed at the conclusion of operations. These commodities would no longer be in the same locations, so this land would no longer be capable of being used for natural gas production or sources of borrow.

Short-term effects on land use would be minor south of 59°15' N. latitude because they would not be new, but would be additive in that the proposed pipeline would closely parallel existing pipelines, roads, or railroads for much of its length or would be through grain fields or pasture lands in which effects would be barely noticeable during the operation phase. In the Mackenzie Valley the proposed route would occupy the same corridor as the Mackenzie River and the Mackenzie Highway. Except for the actual area occupied by project installations, long-term changes in land-use patterns would be controlled by changing socioeconomic factors that would be, at most, only secondarily affected by a pipeline rather than by the impact of the project on the land. Because of the river and highway, no significant additional accessibility would be afforded by a pipeline. Human presence attributable to the pipeline would contribute to loss of wilderness use, which would in any event have been diminished by the Mackenzie Highway and the development of service facilities along it.

The greatest impact on land use, if the project were completed, would be in the Mackenzie Delta and along the proposed supply lines. Because of the greater need for gravel for construction in permafrost areas, the concentration of borrow pits would be much greater than in other segments of the proposed route (section 1.1.2.3). The mere presence of a pipeline and its ancillary installations would remove an area near the pipeline from wilderness use. Oil and gas exploration along the route of the proposed Richards Island Supply Line, however, have already begun this change in land use.

3.1.2.12 Archeological, Historic, and Other Unique Values

Destruction of Potential Sites

The proposed pipeline would cross an area that was little known archeologically up until a few years ago. Archeology in the western Canadian Arctic has been limited by the difficulties of travel, the short season, and the relatively small results compared to the amount of effort required.

As a resource, archeological evidence is very limited and irreplaceable. It is easily destroyed or lost and once gone is never available again. As part of our heritage, it is protected by law in both Canada and the United States.

Every aspect of the proposed project that involves a land-use activity could cause loss of, or damage to, the archeological resources of the region. Approximately 67 square miles of land would be required for construction of the system--about 80 percent of the total would be for the 120-foot wide right-of-way and the remaining 20 percent for related facilities. The 50 compressor stations would use 1,808 acres, the 21 airstrips would use 2,780 acres, and the 80 communications sites, 19 wharves, 170 helicopter pads, and 26 stockpile sites would use about 900 acres.

River crossings, especially those near the inlets or outlets of lakes have very high archeological potential. Since river crossings would require widening the right-of-way and in some cases, substantial bank cutting, there is considerable potential for destruction of archeological sites. Six high priority river crossing sites have been identified along the northern part of the proposed route by Millar (1974), including crossings of the Fish River, Big Smith Creek, Saline River, River Between Two Mountains, and Willowlake River. South of 60° N latitude, the proposed pipeline would cross more than 20 rivers.

Borrow activities at more than 100 sites would be carried out in inactive flood plains, eskers, etc., places that have considerable potential to contain archeological material. Eskers, for example, once afforded dry, elevated campsites to prehistoric peoples. Construction of sites for compressor and measuring stations, communication relays and stockpile storage could destroy archeological evidence because factors influencing site selection, such as drainage or the possibility of flash flooding, also certainly influenced site selection by early man.

People associated with all phases of construction could cause destruction of archeological sites by knowingly failing to report a find because of uncertainty or because they deem it insignificant. They could fail to report a find because of the delay for investigation that would ensue, or because they wanted to keep it as a souvenir.

The pipeline trench itself would be shear-cut to a depth of 8 feet which would cause the loss or fracture of any artifacts in the 40-square-foot cross section.

Effect on Present and Existing Sites

The proposed pipeline route north of 60° N latitude would not come in contact with any excavated sites identified in archeological publications. It would cross only three areas that have been the subject of previous archeological surveys--the Oscar Creek-Chick Lake area, the Firth River area, and the Ochre and Johnson Rivers area (Millar, 1974). Effects of pipeline construction on these sites would be similar to those discussed in the previous section.

Although known historic sites themselves would not be damaged by construction and operation of the proposed project, esthetic damage to the nearby landscape (clear-cut right-of-way through forested areas, cut and fill operations, compressor stations and other auxiliary facilities) could detract from visitors enjoyment and appreciation of such places as Rocky Mountain House National Historic Park, Fort Walsh, and Chesterfield House.

Increased Accessibility to Potential Sites

One of the limiting factors to archeological research in the western Canadian Arctic has been the relative inaccessibility of the region. The prospect of an excavation over 2,400 miles long (in Canada) and 8 feet deep across a largely unknown and potentially important region is a tremendous challenge and opportunity to the archeological community, especially where permafrost occurs only inches below the surface, making normal archeological effort arduous.

On the other hand, making the region more accessible could lead to destruction of archeological and historic sites by "arrowhead hunters," vandals, and the like.

Increased Number of Known Sites

Even though construction of the proposed pipeline would destroy potential archeological sites, it could also uncover many sites, provided proper salvage measures were undertaken.

The territorial boundary between the Eskimo and adjoining Athabascan populations has long been a matter of conjecture. The zone of interface between these two quite different peoples is vague on the early historic level, and is even more difficult to determine for the prehistoric period. Because the Prudhoe Bay Supply Line tends to follow this zone, and the Richards Island Supply Line traverses it, archeological investigations carried out in conjunction with pipeline construction might clarify the problem (Millar, 1974).

The prehistoric occupants of the Boreal Forest of Canada west of Hudson Bay were speakers of the Athabascan language. There also were a number of isolated pockets of Athabascan speakers as far south as California and New Mexico. As the intermontane plateau of the Yukon Territory and Alaska is thought to be a possible place of origin of these people, whose prehistory has only recently come under investigation, discovery of new archeological sites along the proposed route might contribute to our knowledge of them.

As a result of proposed archeological salvage activities along the proposed route, many other problems related to our lack of knowledge of the region might be solved. In Alberta, for example, the identities of the aboriginal groups, the relationships between regional cultures, the population settlement patterns and population displacement related to the advent of the fur trade are questions which might be answered in part by the discovery of new sites.

Construction of the proposed project probably would not have any significant adverse effect on paleontological resources and actually might contribute to the discovery of new fossil occurrences. Generally fossils are more or less widely dispersed throughout the particular rock stratum in which they have been deposited. Therefore, destruction of all the fossils in that rock stratum by construction activities would be highly unlikely. Since most of the proposed route (except in British Columbia) avoids bedrock areas, there is even less chance of destruction of any fossil localities.

3.1.2.13 Recreational and Esthetic Resources

Recreation Facilities, Areas, and Resources

Construction of the proposed pipeline would have more impact on potential recreation areas and resources than on existing facilities such as Provincial parks, campsites, and private resorts because the route would almost wholly avoid such places. The clearing of the proposed right-of-way would create an unbroken 120-foot-wide swath through the Boreal Forest, thus reducing the photographic appeal of the scenery in some areas. Auxiliary construction, including more than 100 borrow pits, 50 compressor stations, at least 21 airstrips, and more than 80 communication sites, would also mar the landscape for those interested in sightseeing and photography. Other landscape scars would result if underlying permafrost were to be thawed, causing settlement and erosion.

Dall sheep, grizzlies, and polar bears are highly valued hunting trophy animals and disturbance by pipeline-related activities along the coastal segment of the proposed route could reduce their populations over wide areas and thereby severely reduce recreation potential, whether in the form of hunting or observation. Along the Mackenzie River, moose is the dominant big game species, and if excessive hunting by pipeline personnel during the winter construction season were allowed, a decline in the moose population could result, thereby reducing the recreation potential for several years after construction. In addition, harassment of wildlife from low-flying helicopters and other aircraft by project personnel, visiting dignitaries, reporters, etc., could occur. Areas where the impact of low-flying aircraft would be damaging to wild waterfowl include the Mackenzie River from Inuvik to Fort Simpson, the Yukon coastline, Herschel Island, and various places in the Mackenzie Delta. Caribou on the Arctic Coastal Plain would be disturbed by increased air traffic. Other construction disturbances would also cause at least temporary displacement of most game species. During the operational phase of the proposed project, some increased hunting and observation opportunities might occur along the cleared right-of-way in forested areas, aided in part by improved access along proposed project roads.

A possible impact on sport fishing could come from increased fishing pressure by employees of the proposed project during the construction period. In the Mackenzie Delta region, Noell Lake and the smaller lakes of the Travaillant Lake area could be subject to overfishing by pipeline workers, especially since those lakes are presently used by residents of Inuvik and Arctic Red River. Residents of Fort Good Hope use several good fishing lakes such as Chick, Loon, Rorey, and Travaillant for recreational and domestic fishing, and the added fishing pressure from pipeline workers could result in overuse. In the South Mackenzie region, seven proposed compressor stations are within 50 miles of at least eight lakes with known or suspected sport fishing potential. As the proposed compressor stations would be under construction year round with some 100 to 200 men involved at each station, the lakes (Dogface, Trout, Sibbeston, Antoine, Cli, Dock, Fish, and Kelly) could come under heavy fishing pressure, there being little opportunity for other recreation.

Although no permanent roads are proposed along the Prudhoe Bay Supply Line, the continued presence of men and related aircraft traffic to maintain the proposed line and the compressor stations would eliminate the Coastal Region as wilderness area.

A compressor station is proposed for the mouth of the Rat River, a white-water canoeing-type stream and former canoe route to the Yukon gold-mining area. The station and facilities would eliminate potential campsites and would detract severely from a wilderness-type experience, an experience which is an important part of white-water canoeing. Another good canoeing stream is the Great Bear River; the proposed pipeline would only cross this river some 4 miles from its junction with the Mackenzie River and thus should not greatly reduce its value as a canoe route.

Where the proposed route parallels the Mackenzie Highway or other planned or existing roads, it could eliminate some potential campsites for highway travelers. Some of the potential sites that would be eliminated include Big Smith Creek, Hanna River, Thunder River, Tidea River, Canyon Creek, Francis Creek, Prohibition Creek, Helava Creek, and Christina Creek. Some loss of recreation quality would occur in the immediate vicinity of construction activity from noise, smoke, dust, etc. During the life of the project impact would occur at the proposed compressor stations, in the form of noise, visual impact and possible air pollution. Further impact could occur during construction from road congestion and competition for limited services in such isolated areas as Fort Simpson, Fort Norman, and Norman Wells, especially during peak recreation periods.

Esthetics

In the Arctic Coastal Plain (zones A and B) (see Figure 2.1.2.13-1), the proposed pipeline, when viewed from the air, would appear as a heavily disturbed trail cleared for seismic exploration for 3 to 5 years following construction, and possibly longer. A successful revegetation program would reduce impact but the line still would be visible for decades as has been the case for other lines through a variety of vegetation types in other parts of the world. For on-the-ground viewing, the backfill mound and other evidence of construction would spoil vistas and general scenery.

The Mackenzie Delta Region (zones C and D) has been subjected to much seismic exploration, resulting in a grid pattern of seismic lines spaced 1 to 3 miles apart. Between Fort McPherson and Inuvik, the cleared right-of-way would appear as an extra-wide seismic line. North of Inuvik, the proposed pipeline would appear similar to a wide seismic line and since the area is already crossed by numerous seismic lines the impact on aerial viewing would not be severe. To a ground-level observer, the proposed pipeline would not be obvious due to the general flatness of the area.

Within the north Mackenzie region (zones E and F), the proposed pipeline and the Mackenzie Highway generally would be within a mile or two of each other for approximately 470 miles, except for short sections totaling about 65 miles in which the highway and the pipeline would be some 4 to 8 miles apart. As the area is basically level and covered by great expanses of forest, the linear alignment of the proposed pipeline would add to the visual impact of highway and seismic lines as seen from an aircraft or elevated vantage point in the mountains. It would be less obtrusive when viewed from the ground.

South of Camsell Bend (zone G), the area is crisscrossed by seismic lines spaced generally 2 to 3 miles apart. From an elevated vantage point, the proposed right-of-way would have visual impact as a clear-cut, mechanically straight swath through the Boreal Forest although this impact would be lessened somewhat by the presence of the highway and seismic lines. From ground level, it would be screened by forest cover from all vantage points other than those directly along the alignment. Proposed compressor stations at the River Between Two Mountains and Oscar Creek would impair two good views of the mountains, and the view of a scenic waterfall on Bosworth Creek could be marred by the proposed pipeline crossing downstream.

In northern Alberta (zone H) (see Figure 2.1.2.13-2), the visual impact of a clear-cut swath through forest cover would be greatest from the air. At ground level, the proposed pipeline would be screened by trees from vantage points other than those directly along the right-of-way.

West of Lesser Slave Lake (zone I), visual impact would be low on agricultural land, as the proposed pipeline would not interfere with cultivation of land it crossed. Revegetation measures could lessen the visual intrusion of a clear-cut right-of-way crossing from open agricultural land to aspen parkland.

The level forested terrain west of Edmonton (zone J) would be subject to visual impact similar to that expected in forested areas to the north (highest visual impact from the air, little impact from ground level).

In the area near Calgary (zone K), there would probably be only minor visual impact on agricultural land, and revegetation measures could soften the impact on aspen-covered foothills.

In southeastern British Columbia (zone L), extreme variations in elevation create vantage points from which the length of the proposed right-of-way could be viewed from a distance. Cut-and-fill operations would disturb the natural contours of the landscape and even if revegetation measures were taken, the proposed pipeline would probably remain highly visible for several years.

In southeastern Alberta (zone M), transition of the proposed pipeline alignment from the low elevation of coulees to elevated tableland would create some problems that could be visually disrupting.

In southwestern Saskatchewan (zone N), the visual impact of the proposed pipeline would be low because it would not interfere with cultivation of the agricultural land it would cross, provided that topsoil was replaced after installation of the pipe.

3.1.2.14 Air Quality

Air quality along the pipeline route will be impacted during construction and subsequently at compressor station locations during operation of the pipeline. Factors which will have an impact are: exhaust emissions from construction equipment engines, dust produced by construction activities, exhaust emissions from compressor stations, and release or escape of gas from the pipeline.

Exhaust Emissions From Construction Equipment

The Applicant has stated that the construction equipment will consume about 160,000 tons of gasoline, diesel fuel, and lubricants. About 80 percent of the construction equipment will be diesel powered. The following amounts of emissions (in tons) will be produced during construction of the pipeline:

	CO	UHC	NO_x	SO_2	Particulates
Gasoline powered equipment	6,800	600	340	25	32
Diesel powered equipment	180	400	663	120	327
TOTAL	6,980	1,000	1,003	145	359

These emissions would be generated during the 3-year construction period and would be over the 2,435 miles of pipeline. The locations where the air quality impact will be the greatest are areas of concentrated construction activity such as river crossings and areas where inversions and ice fog can occur such as river basins.

Emissions From Compressor Stations

There will be 50 compressor stations located along the route; 15 of these will also have 17,000-hp refrigeration systems for gas cooling. Although the Applicant has not submitted detailed emission data on the compressor stations, it is probably reasonable to assume that they will be similar to those proposed by other pipeline applicants and those tested by the Southwest Research Institite for the ASME. The estimated stack emissions from each compressor/refrigerator station based upon ASME data, Bulletin 75-DGP-20 (Dietzmann), are as follows:

Compressor Station Consisting of 30,000-hp Compressor
and 17,000-hp Refrigerator

NO_x - 134 lb/hr

CO - 4.66 lb/hr

UHC - 9.32 lb/hr

SO_2 - 9.38 lb/hr (if sulfur level in gas is about 20 grains/100 cubic feet)

Compressor Station Consisting of 30,000-hp Compressor

NO_x - 40 lb/hr

CO - 5 lb/hr

UHC - 6 lb/hr

SO_2 - 6 lb/hr

Compressor Station Consisting of Two 27,500-hp Compressors

NO_x - 80 lb/hr

CO - 5 lb/hr

UHC - 12 lb/hr

SO_2 - 12 lb/hr

Analytical methods have been developed which predict the dispersion of emission. Assuming that the compressor station can be treated as a prime source, then the estimates of emission rates, wind speeds, inversion propensity, and stack height can be used to compute the NO_x concentration about the source. These estimates are as follows:

Distance From Source	Inversion Worst Case	Normal Most Frequent Case
500 m	491 $\mu g/m^3$	33 $\mu g/m^3$
1,000 m	262 $\mu g/m^3$	18 $\mu g/m^3$
10,000 m	32 $\mu g/m^3$	2 $\mu g/m$

The limit set by the EPA's National Air Quality Standards for the annual arithmetic mean is 100 $\mu g/m^3$.

The tariff proposal of the Applicant suggests that there may be as much sulfur content as 20 grains/100 cubic feet of gas. If this is so, the sulfur dioxide level in the emissions will rise.

At present, behavior of emissions within ice fogs has not been researched to enable predictability; however, it is known that a large percentage of ice fog particles do have particulate nuclei. As the compressor stations will be expelling both nuclei and water vapor, it may be assumed that ice fog will form and be a problem. The stack effluent will contain about 26,000 lb/hr of water vapor, which would form 32,000,000 cf/hr (cubic feet/hour) of ice fog (Ohtake, 1970). Areas along the Arctic coast may expect 90 days annually of fog and 118 days of visibility of less than 1 mile.

Lichens are very sensitive to sulfur dioxide. Tests have determined that SO_2 concentrations below 0.002 ppm are not injurious to lichens, that between 0.006 and 0.03 ppm chronic exposure may cause injury, and that above 0.03 ppm, acute exposure (hours or days) may cause injury. If as much as 20 grains per hundred cubic feet of total sulfur were permitted in the gas, then under very high wind conditions (25 mph) it would be possible for concentrations to rise on the ground as high as 0.006 ppm. More likely, however, would be temporary conditions of 0.01 ppm with 10 grains per hundred cubic feet and 5 mph winds. Since these would be short duration exposures under the usual variations of wind speed and direction, it is most likely that the chronic exposure of lichen will be below the chronic damage threshold for epiphytes.

Dust Due to Construction

Dust will be produced by construction equipment and the amount produced will be a function of soil conditions, meteorological conditions, and equipment activity. Most of the dust will be produced during construction activities in agricultural land along the southern parts of the route during the summer. Pipeline construction is similar to conventional highway construction and about 5 tons of dust per mile will be generated. Dust produced on adjacent non-paved access roads will be in the order of about 0.10 tons per pipiline mile.

Dust will also be produced at gravel mining and crushing sites but can be effectively controlled by water sprays located on the equipment.

3.1.2.15 Environmental Noise

The predicted impact of noise emissions from the proposed pipeline is addressed separately for humans and wildlife. The impact is further subdivided in terms of the construction phase and the operational phase. In general, the construction noise will be short term and widespread, while the operational noise will be long term and more localized.

Effects on Humans

Construction Phase

The construction phase will produce both indirect and direct noise impacts. The indirect noise impact will be due to the road traffic generated by the project and the direct will be construction site noise.

Road Traffic

The primary cause of noise impact due to road traffic will be heavy diesel trucks hauling construction equipment and pipe. Since most of the construction equipment will remain on the site, except when hauled around major waterway obstacles, the pipe hauling operation is estimated to create the largest impact. It was not possible to precisely determine the population who will be exposed to hauling truck traffic since many access roads will need to be constructed and their exact locations have not been decided. The populations existing along the existing major highways designated by the Applicant as access roads are enumerated in Table 3.1.2.15-1.

Right-of-way Construction

Construction of the pipeline along the right-of-way will require large numbers of heavy equipment which will operate as groups doing various phases of the construction. Most of this equipment will be diesel engine powered. Typical noise levels (in dbA at 50 feet) of construction equipment are given in Figure 3.1.2.15-1 (U.S. EPA, 1972). These are levels that are found while the equipment is performing its task and would represent those levels observed on the pipeline construction site. It has been estimated that the welding equipment would be acoustically similar to stationary air compressors.

The energy mean of the L_{eq} values measured at 24 sites during excavation (corrected to a distance of 50 feet) is 84 dB (N.Y. Dept. of Env. Cons., 1974). Using this value as representative of the day-night sound level (L_{dn}) at 50 feet (since there is no nighttime construction planned), it is predicted that a total of 978 people will be exposed to construction noise in excess of the U.S. Environmental Protection Agency (EPA) goal of $L_{dn}=55$ (designed to protect human welfare) (U.S. EPA, 1973). As a result, it is anticipated that about 464 people will be highly annoyed by the noise and about 18 will complain to authorities about it. These impacts will be distributed over the entire route and over the total period of construction. Quantification of the impacts of construction noise by province is given in Table 3.1.2.15-2.

Blasting and Vibration

Blasting operations during the construction phase will produce direct impacts on any nearby structures.

Drilling and blasting will be required where trenching through rock cannot be accomplished by ripping and removing the loose material with a backhoe. The detonation of explosive materials induces transient motion in the rock which is then transmitted through the surrounding rock and through any overlying or underlying strata. It is this motion, referred to as ground motion, which directly or indirectly damages structures. Direct damage of structure occurs when the motion produces stress levels sufficient

Table 3.1.2.15-1 Communities potentially impacted by truck hauling activities

Access Highway	Communities (Population) Along Highway	Total Population
Trans-Canada Highway	BRITISH COLUMBIA: Abbotsford (706), Chilliwack (9,135), Choate (?), Yale (?), Spuzzum (?), Chapmans (?), Boston Bar (125), Lytton (494), Shaw Springs (?), Spences Bridge (199), Cache Creek (?), Savana (?), Kam Loops (26,168), Pritchard (?), Chase (1,212), Squilax (?), Notch hill (100), Tappan (?), Salmon Arm (1,981), Solsqua (?), Silcamous (?), Malakwa (?), Craigellachie (?), Taft (50), Three Valley (?), Revelstoke (4,867), Albert Canyon (?), Donald Station (?), Blaeberry (?) Golden (3,010), Field (358) ALBERTA: Lake Louise (150), Banff (3,219), Canmore (1,538)	52,818
Calgary to Edmonton Highway	ALBERTA: Balzac (?), Airdrie (327), Bowden (560), Ellerslis (?)	887
Edmonton to Peace River Highway	ALBERTA: Spruce Grove (3,029), Stoney Plain (1,770), Onoway (?), Glenevis (?), Cherhill (120), Sangudo (360), Rochfort Bridge (?), Manerthorpe (563), Green Court (50), White Court (3,200), Fox Creek (?), Little Smokey(?) Valley View (1,678), Guy (?), Donnelly (265), Nampa (?), Peace River (5,039)	16,024
Peace River to Hay River	ALBERTA: Peace River (5,039), Dixonville (?), Meander River (?) NORTHWEST TERRITORIES: Hay River (2,406)	7,445
Hay River to Fort Simpson Highway	NORTHWEST TERRITORIES: Hay River (2,406), Fort Simpson (747)	3,153
Alaska Highway	ALBERTA: Valley View (1,678), Crooked Creek (?), Debolt (?), Goodwin (?), Grande Prairie (6,302), Bezanson (?), Wembley (272), Beaver Lodge (1,157), Hythe (487), Demmit (?) BRITISH COLUMBIA: Tupper Creek (200), Pouce Coupe (595), Dawson Creek (11,885), Farmington (?),Pine Valley(?) Taylor (?), Ft. St. John (8,264), Charlie Lake (?) YUKON: Teslin (340), Whitehorse (11,217), Champagne (?), Kluane (?), Burwash Landing (?)	42,397

Table 3.1.2.15-1
(Contd.)

Access Highway	Communities (Population) Along Highway	Total Population
Ft. Macleod to Kingsgate Highway	ALBERTA: Ft. Macleod (2,109), Brocket (?), Pincher Station (?) Cowley (92), Coleman (1,566), Blairmore (2,037), Crows Nest (?) BRITISH COLUMBIA: Michael (21), Natal (158), Hosmer (125), Fernie (4,422), Elko (230), Jaffray (?), Wardner (200) Cranbrook (12,000), Lumberton (?), Moyie (225), Yahk (100), Kingsgate (50)	23,335
DEMPSTER (Part is proposed)	NORTHWEST TERRITORIES: Inuvik (2,669), Ft. McPherson (679) YUKON: Dawson (762), Carmacks (348), Whitehorse (11,217)	15,675
Proposed Mackenzie Highway	Ft. Good Hope (327)	327
TOTAL		162,111

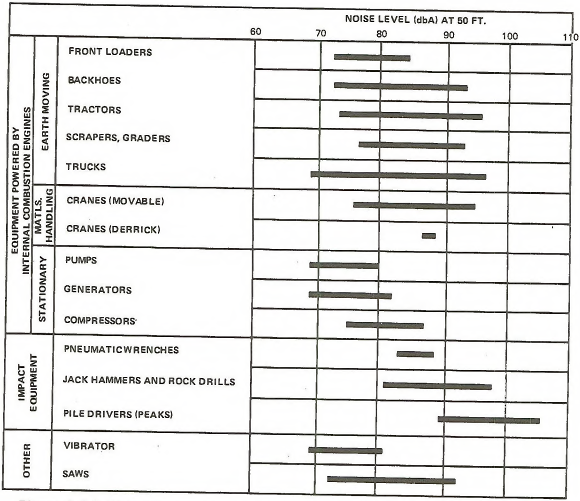


Figure 3.1.2.15-1 Construction equipment noise ranges

Table 3.1.2.15-2 Impact of pipeline construction noise on people in Alberta and Saskatchewan

Canadian Province	Estimated Number of People Impacted by a $L_{dn} > 55$ dB**	Estimated Number of People Highly Annoyed	Estimated Number of Complaints
Alberta	835	421	16
Saskatchewan	143	43	2
TOTAL	978	464	18

* Estimates are conservative, since the aerial photos from which the counts were taken were often not of sufficient clarity or scale to enable identification of homes. This was also the case for The Yukon, Northwest Territories and British Columbia.

** The day-night sound level (L_{dn}) has been identified by the U.S. EPA as the maximum level permissible to protect human welfare. Factors for normalizing L_{dn} do not apply here.

to cause structural failure such as cracking of foundations, loosening of mortar and other damage to primary structure. Safe limits of ground motion from blasting (Crandell, 1949; Hendron & Oriard, 1972; Soliman, 1973; Steffens, 1966), for structures, building components and sensitive equipment, have been established at an acceleration level of 38.6 inches per second per second from 5 to 15 Hz and a velocity level of 0.4 inch per second above 15 Hz. Below these levels structural failure generally does not occur but rather a secondary effect may occur which is the settlement or compaction of soil caused by ground motion.

Under sustained vibratory loads or repeated impacts such as caused by blasting operations, the internal structure of soils may change, thereby producing settlement of surface or possibly a reduction in strength. It is well known that loose, saturated cohesionless soils are particularly susceptible to compaction by impacts or vibration.

For example, damage from traffic-induced ground motion in medieval cathedrals of England and Wales has been investigated and predominant cracking and settlement was reported within those structures located adjacent to roads even though the ground motion levels were substantially below those specified as safe limits (Crockett, 1963).

Blasting will be required along a 31-mile stretch of the Kingsgate Delivery Line where hard bedrock is encountered. No buildings could be located which are close enough to the proposed line to be affected. Communities within 5 miles of the blasting are enumerated below:

Community	Estimated Distance From Proposed Pipeline (miles)
Elko	4.5
Courier	4
Big Sand Creek	3
Colvalli	4
Jukeson	5
Aldridge	1.5
Moyie	3

Ground vibration caused by construction equipment and hauling trucks is estimated to be sufficiently small at any vibration-sensitive buildings that no adverse impact can be identified. See Section 3.1.3.2 for the effects of blasting and vibration on creating rockfalls and landslides.

Compressor Station Construction

Construction of the compressor stations will entail only small amounts of grading; most of the activity will be hauling of materials and construction of the buildings. Those activities should be of short duration and spread out over several months, starting with clearing the site to installing the compressors. Because of the low population density at rural locations, very few complaints, if any, are expected, and no legal action against the Applicant as related to noise would be expected either.

Operation Phase

Compressor Stations

The major potential noise sources of significance during the operational phase of the project are the compressor stations, which will be continuous and fixed noise sources.

Table 3.1.2.15-3 shows the estimated impact of gas compressor station noise emissions on people residing nearby. A total of 79 people are estimated to reside within an area impacted by compressor station noise in excess of the U.S. EPA goal for welfare. It is further estimated that 17 people will be highly annoyed, but none will complain.

Blowdown

Periodic venting of high pressure gas from the compressor stations or along the line would cause temporary but severe increases in sound level (Table 3.1.2.15-4). These blowdowns will occur either because of an emergency or as a part of maintenance check or repairs. Blowdown of a compressor, or a pipeline section ending at a compressor station (unit blowdown), would occur at the station. Blowdown of a pipeline section would occur at each end of the section.

Station blowdowns are predicted to occur 3 times per year per station. Unit blowdowns are expected to occur 6 to 12 times per year per station. It is estimated that the maximum noise would occur over most of the period which is approximately 5 minutes for a station blowdown and 45 minutes for a pipeline blowdown.

Based on this data and the approximate attenuation data given in Section 2.1.2.15, it is estimated that a station blowdown would be near 70 dB at 3 miles. Because of its relatively short duration and infrequent occurrence, it will cause annoyance but may not result in complaints to authorities.

Effect on Wildlife

There are no definitive studies which would enable quantification of the long-term impact of pipeline related noise on wildlife. Studies do indicate that the most probable effect will be to reduce utilization of habitat areas impacted by noise. Whether this effect will be long or short term is unknown and is likely to be variable between species.

Construction Phase

Very little research has been completed on the reaction of wildlife to construction noise. Since construction noise is temporary, it is probable that the impact, if any, will be short term.

Caribou

R. Korzan (personal communication as cited in Calef, 1974) reported that caribou can tolerate winter blasting if they have not been subjected to hunting; their reactions during the summer have not been observed. North of 60° N. latitude, 17 miles of the proposed pipeline have been identified as potential caribou winter range.

Table 3.1.2.15-3 Impact of gas compressor station noise on people

Station Number**	hp	Estimated nbr of People Impacted by a Normalized $L_{dn} > 55$ dB*	Estimated nbr of People Highly Annoyed by Station Noise	Estimated number of Complaints
M-25	55,000***	3	1	0
E-00	30,000	19	5	0
E-01	30,000	18	3	0
E-02	30,000	3	1	0
E-05	30,000	5	1	0
K-00	30,000	31	6	0
Total Impact		79	17	0

* A day-night sound level (L_{dn}) of 55 dB has been identified by the U.S. EPA as the maximum level permissible for protection of human welfare. L_{dn} has been normalized to correct for quiet, rural communities (10 dB) and for no prior experience with the noise (5 dB).

** Compressor stations not listed above either had no people residing within the L_{dn} of 55 dB or the number of people could not be determined.

*** Total hp of 2 compressors in series.

Table 3.1.2.15-4 Blowdown noise*

Distance (ft.)	Station Blowdown		Unit Blowdown
	16" Valve Vent	10" Valve Vent	
100	115 dBA	113 dBA	108 dBA
300	105 dBA	104 dBA	98 dBA
1,000	94 dBA	93 dBA	87 dBA
3,000	84 dBA	82 dBA	75 dBA

* No silencing measures taken.

Dall Sheep

Sheep were observed to interrupt their activities in response to sound levels of 105 decibels (weighting not specified) produced by blasting 3.5 miles away and even these moderate reactions appeared to decrease over time (Lent and Summerfield, 1973 as cited in Reynolds, 1974).

Grizzly Bears

It is possible that winter bear dens may be disturbed by grading, ditching or borrow operations (Kucera, 1974). The same soil types which typically harbor bear dens are also best suited for borrow operations (Slaney & Co., 1973a and Jakimchuk et al., 1974, as cited in Kucera, 1974). It is estimated that construction operations located at least 1,500 feet from a den will not rouse the occupants (Craighead, personal communication and Pearson, personal communication as cited in Kucera, 1974). Jonkel (personal communication as cited in Kucera, 1974) reported that a black bear did not leave its den which was located approximately 300 feet from highway construction activities.

Moose

No research has been completed on the effects of construction noise on moose, but it is likely that there will be several contacts. North of the 60° N. latitude, 107 miles of the proposed pipeline route pass through moose winter range. Eighty-five miles pass through areas where moose are sensitive to disturbance during November and December. There are 10 miles which have year-round use by moose.

Snow Geese, Canada Geese, White-Fronted Geese and Whistling Swans

Birds with young would not approach a drilling rig within a radius of 2-2/3 miles (Barry and Spencer, 1971 as cited in Jacobson, 1974).

Peregrine Falcons

F. Beebe (personal communication as cited in Jacobson, 1974) commented that falcons will accommodate to construction noise, excluding explosives, if it is not centered near the nest. Herbert and Herbert (1969 as cited in Jacobson, 1974) noted that six nests were deserted in response to construction activities.

Operation Phase

Gas Compressor Stations

Several studies have been performed to determine the response of wildlife to gas compressor station noise (McCourt, et al., 1974; Reynolds, 1974; Gollop, Goldsberry, et al., 1974a; and Gollop and Davis, 1974). These investigations all utilized a system designed by J-mar Electronics which consisted of a number of loudspeakers, noise generators, and filters to reproduce the noise of a 20,000-HP gas compressor station.

The maximum horizontal distance at which different wildlife species have been observed to react to simulated gas compressor station noise is presented in Table 3.1.2.15-5. It is predicted that these are the maximum

Table 3.1.2.15-5 Maximum horizontal distances at which wildlife react to gas compressor station noise

Wildlife	Estimated Maximum Horizontal Distance (ft) of Reaction as a Function of Station Horsepower				
	SIMULATOR*	PROPOSED STATION HORSEPOWERS**			
	20,000 hp	30,000 hp	47,000 ph	55,000 hp	64,000 hp
Caribou	2,640	2,750	3,300	3,500	3,800
Dall Sheep	5,280	5,700	6,800	7,300	7,900
Ground Squirrels	0	0	0	0	0
Red Foxes	5,280	5,700	6,800	7,300	7,900
Snow Geese	15,840	15,840+	15,840+	15,840+	15,840+
Lapland Longspurs	2,980	3,200	3,800	4,000	4,350

*These distances are based on observed reactions of wildife to a simulator of noise emissions from a 20,000 hp station.

**These distances are adjusted to account for the additional horsepower of the proposed stations. The horsepowers listed for the proposed stations are the sum of compressors in series and refrigeration units.

distances at which decreased utilization of habitat will result from gas compressor station noise.

The estimated maximum land areas which are either avoided or have decreased usage by wildlife in response to gas compressor station noise are presented in Table 3.1.2.15-6. The impact of this habitat loss on wildlife survival cannot be interpreted without data regarding the total amount of suitable habitat area available to the wildlife, the present degree of utilization, and the carrying capacity.

Caribou--McCourt, et al., (1974) concluded that caribou will tend to avoid a gas compressor station within a radius of 1/8 mile and may make decreased use of an area within 1/2 mile of a station. Deflection around stations was observed at calving grounds and during spring migration, summer movement, and fall migration, though the distances at which the avoidance occurred and the percentages of caribou deflecting differed by season.

Dall Sheep--Seventy-five percent of the sheep observed abandoned their summer range to within 1 mile of a gas compressor station simulator (McCourt, et al., 1974). Mineral licks were not abandoned by sheep, but there was decreased usage of areas closest to the simulator at licks 1/4 and 3/4 miles away (Reynolds, 1974). Three explanations may be proposed for the differences in the reaction of Dall sheep to compressor station noise on their summer range and mineral licks. They are: differences in the (1) proximity of alternative habitat, (2) amount by which the simulator noise exceeded the ambient at the sheep's location, and (3) prior exposure to aircraft noise (Reynolds, 1974).

Ground Squirrels--Simulated gas compressor station noise did not affect the number of squirrels nor the activities in which the squirrels were involved (Reynolds, 1974). Therefore, gas compressor stations are predicted to have no impact on ground squirrels.

Red Foxes--Foxes ceased hunting within a 1-mile radius of a simulator of gas compressor station noise (Reynolds, 1974).

Snow Geese--Snow geese initially deserted an area within 3 miles of a simulator of station noise. Some later returned to within 1-1/2 miles only to leave again when a plane landed nearby (Gollop and Davis, 1974).

A significantly fewer number of flocks circled and landed near decoys when impacted by simulator noise. (The decoys were placed within 600 feet of the simulator.) A significantly greater number of flocks flared (veered sharply away and gained altitude) or altered their direction of flight when impacted by simulator noise (Gollop and Davis, 1974).

Sixty-one percent of snow geese flying towards a simulator of gas compressor station noise were observed to alter their flight direction by greater than 90 degrees. Gollop and Davis (1974) suggest that gas compressor stations, if located near staging areas, may result in decreased conservation of energy by forcing the geese to make wide detours around the station when flying between feeding areas. This may indirectly increase the snow geese mortality rate by increasing the probability that the geese will commence their southern migration with less stored energy and thereby be forced to make more stops along the way. This, in turn, will increase the probability of hunting mortality (Gollop and Davis, 1974).

Table 3.1.2.15-6 Maximum land area north of 60° N latitude avoided or having decreased usage by wildlife due to noise emissions from gas compressor stations

Wildlife	# of Proposed Station in Their Vicinity as a Function of Station Horsepower				Estimated Total Land Area (sq.mi.) Avoided or Having Decreased Usage by Wildlife
	30,000 hp	47,000 hp	55,000 hp	64,000 hp	
Caribou	2	5	1	0	9
Moose	1	11	1	1	*
Grizzly Bears	0	2	0	1	*
Black Bears	0	2	0	0	*
Foxes	0	8	0	1	49

* The total maximum land area avoided or having decreased usage by Moose, Grizzly Bears and Black Bears cannot be estimated, since their reaction distances to gas compressor stations have not been investigated.

Lapland Longspurs--Nesting longspurs did not desert their nests which were located within 2,980 feet of a simulation of station noise, but there was a tendency for the percentage of eggs hatched to decrease and for the predation rate to increase (Gollop, Goldsberry, et al., 1974a).

Aircraft

The Applicant states that surveillance aircraft will fly above the pipeline approximately once per week at an altitude of 200 feet over most areas and 500 feet over wildlife areas. Aircraft being used primarily for transportation and other purposes will be flown at a 2,000-foot altitude. The maximum diagonal distances at which different wildlife species have been observed to react to aircraft are converted into maximum horizontal distances as a function of aircraft altitude in Table 3.1.2.15-7. It is predicted that these are the maximum distances at which habitat utilization will be reduced due to aircraft inspection flight along the pipeline.

The estimated maximum land areas which are either avoided or have decreased usage by wildlife in response to pipeline surveillance flights is presented in Table 3.1.2.15-8. The impact of this habitat loss on animal survival cannot be interpreted without data regarding the total amount of suitable habitat area available to the wildlife, the present degree of utilization and the carrying capacity.

Sound levels of overhead aircraft flybys are presented in Table 3.1.2.15-9.

Caribou--An altitude of 500 feet is the approximate threshold for caribou reaction (walk or run away) to both fixed wing and rotary aircraft; above this altitude, aircraft will elicit a response from less than 50 percent of the caribou (McCourt, et al., 1974). McCourt, et al., (1974) estimate that 1,000 feet is the minimum tolerance altitude for caribou. At altitudes above 1,000 feet, aircraft provoke inconsistent responses from caribou. Jakimchuk, et al., (1974) observed 30,000 caribou to "flee frantically" a helicopter flying between 500 and 1,500 feet.

The reaction of caribou to aircraft was demonstrated to vary not only with flight altitude, but also as a function of caribou group size, the activity of the caribou previous to disturbance, caribou sex, season, and terrain (Jakimchuk, et al., 1974; Klein, 1973; McCourt, et al., 1974; McCourt and Horstman, 1974; and Calef, 1974).

When caribou evade an aircraft's approach they are expending energy at the rate of 64 kilocalories per minute of running and 20 kilocalories per minute of walking (Geist, 1971 as cited in Klein, 1973). This energy loss must be countered by increased food consumption or body food reserves will be decreased (Klein, 1973). This impact is more hazardous to the survival of caribou during the winter and fly seasons (Geist, 1971). If this energy loss results in a 17 percent loss in body weight or more, pregnant caribou in early gestation may reabsorb their embryos (Geist, 1971). Flight from aircraft may also result (1) in abortion, if the snow is deep and has a hard crust, or (2) in the trampling of the newly born at calving time (Geist, 1971).

Dall Sheep--J.D. Feist, et al., (1974) state that sheep "were markedly disturbed by helicopters at distances up to one mile away." Eighty-five percent of sheep exposed to a helicopter flying at a diagonal distance of 300 to 500 feet exhibited panic running (36 percent) or walked up to 300

Table 3.1.2.15-7 Maximum distances at which wildlife react to aircraft noise

Wildlife	Estimated Maximum Diagonal Distance (ft) of Reaction to Aircraft*	Estimated Maximum Horizontal Distance (ft) of Reaction as a Function of Flight Altitude		
		200 ft	500 ft	2,000 ft
Caribou	1,000	980	866	no reaction
Dall Sheep	5,280	5,276	5,256	4,887
Moose	600	566	332	no reaction
Grizzly Bears	1,000	980	866	no reaction
Black Bears	1,000	980	866	no reaction
Wolves**	0	no reaction	no reaction	no reaction
Wolves***	1,000	980	866	no reaction
Snow Geese	26,403	26,402	26,398	26,327
Canadian Geese	5,654	5,650	5,632	5,288
Waterfowl	5,280	5,276	5,256	4,887
Black Brants	10,560	10,558	10,548	10,369
Common Eiders	3,000	2,993	2,958	2,236
Glaucous Gulls	3,000	2,993	2,958	2,236
Arctic Terns	1,000	980	866	no reaction

* Whenever sufficient data was available on reaction to fixed-wing aircraft, it was used in preference to rotary-wing maximum reaction distances.

** If aerial hunting is prohibited.

*** If aerial hunting is not prohibited.

Table 3.1.2.15-8 Aircraft noise*

Aircraft Type	HP Rating	Normal Cruising Speed (MPH	Sound Level (dBA) as a Function of Altitude		
			100 ft	200 ft	500 ft
Piper Supercub	150	94	90	81	78
Cessna 185	300	145	103	92	85
Helicopter (FH 1100)	274	95	95	82	81

* Table reproduced from Klein, 1973.

Table 3.1.2.15-9 Maximum land areas north of 60° N latitude avoided or having decreased usage by wildlife due to noise emissions from pipeline surveillance aircraft*

Wildlife	Estimated Total # of Pipeline Miles**	Estimated Maximum Area (sq. mi.) Avoided by Wildlife
Caribou	597	196
Moose	564	71
Grizzly Bears	322	106
Black Bears	103	34
Wolves***	227	0
Wolves****	227	74

* Assumes a flight altitude of 500 feet.

** Reference: Northern Engineering Services Co., Ltd.

*** If aerial hunting of wolves is prohibited.

**** If aerial hunting of wolves is permitted.

feet away (49 percent) (Lenarz, 1974). There was no significant difference in their degree of reaction to helicopters as a function of season, aircraft location (above, level with, or below sheep) or group size (Lenarz, 1974).

A helicopter caused 9 out of 10 male sheep to leave the area after 2 hours of exposure; 3 hours after the helicopter left, the sheep began to return (McCourt, et al., 1974). Sheep evidenced decreased usage of traditional areas subsequent to pipeline activities involving rotary and fixed-wing aircraft and communication tower generator noise (Linderman, 1972 as cited in Kucera, 1974).

The reaction distance of sheep to fixed-wing aircraft was not studied. Jakimchum, et al., (1974) state that sheep flee fixed-wing aircraft at relatively high altitudes. Reynolds (1974) noted that sheep at mineral licks would only look towards fixed-wing aircraft at distances of 1/4 to 3/4 mile away.

E. Kucera (1974) suggests that energy loss from aircraft avoidance activities may affect sheep survival, natality, and abortions in the same manner as discussed with regard to caribou. The age at which sexual maturity is attained and all other phases of the reproductive process are dependent upon the nutritional state of the sheep (Summerfield, 1974), which can be affected by evasive activities.

Moose--At altitudes of 200 feet or less, more than 50 percent of moose react to fixed-wing aircraft by running, trotting, or discontinuing the activity in which they are engaged (McCourt, et al., 1974). Similar reactions are obtained from 38 percent of moose exposed to aircraft flying at altitudes of 200 to 600 feet (McCourt et al., 1974). Doll, et al., (1974) also indicate that the frequency of moose reaction to aircraft is inversely related to flight altitude.

Moose which run from aircraft are usually cows with calves (Klein, 1973). Jakimchuk, et al., (1974) state that "moose appear to be disturbed more readily by aircraft during late winter and in deep snow conditions."

Moose approached too closely may show aggression towards the aircraft (Ruttan, 1974).

Grizzly Bears--Grizzly bear reactions are highly variable and are not consistently related to aircraft altitude (McCourt et al, 1974; Ruttan, 1974b). The greatest distance at which bears were observed to run in reaction to a helicopter's approach is one-half mile (Ruttan, 1974b). Eighty percent of the bears, observed by McCourt et al (1974), reacted to fixed-wing aircraft flying at altitudes greater than 1,000 feet by interrupting their activity or by walking, trotting or running away. Seventy-five percent of grizzlies, observed by Doll et al (1974), reacted to an unspecified type of aircraft by running (52 percent), backing off, gathering cubs or watching. The percentages of bears running from fixed-wing and rotary aircraft were 58 and 71 percent, respectively, as observed by Quimby (1974).

Ruttan (1974b) noted that bears would show aggression towards helicopters, rather than desert a kill. Quimby (1974) observed that a single pass by a helicopter flying at 100 feet would normally force a bear to temporarily desert his kill.

Fifty percent of the bears tracked by aircraft abandoned their den sites (Quimby, 1974). Quimby (1974) suggests that energy loss from actions taken by bears to evade aircraft could have deleterious effects on their ability to store sufficient energy for the winter denning period.

Black Bears--Black bears have been observed to run from aircraft flying at altitudes between 100 and 1,000 feet 40 percent of the time (Doll et al, 1974).

Musk Oxen--No distances were recorded in observations of musk oxen reactions to aircraft. Roseneau and War (1974) suggest that heavy helicopter traffic may have resulted in a 16-mile shift of a traditional summer range. R. Hubert (personal communication cited in McCourt and Horstman, 1974) states that musk oxen in undeveloped areas react strongly to aircraft, whereas those located in the vicinity of airfields evidence mild or no reaction at all, indicating an ability to adapt. Schweinsburg (1974a) commented that musk oxen sighted during an aerial survey of bird populations did not appear to be frightened. Musk oxen have been observed to form their characteristic defense circle when approached by aircraft and then break into butting contests (Spencer and Lensink, 1970, as cited in Kucera, 1974). Gray (1971, as cited in Kucera, 1974) reported that though a herd might hold ground during an aircraft passby, oxen often desert the area at a run once the aircraft is gone.

Wolves--Percentages of wolves reacting to aircraft by scattering, making rapid escape, trotting, running or evidencing panic were 79, 31 and 42 percent for flight altitude categories of 25 to 100 feet, 200 to 500 feet and 600 to 1,000 feet, respectively (Doll et al, 1974).

Wolves readily adapt to aircraft noise if they are not subjected to aerial hunting (Klein, 1973, and Mech, 1970).

Foxes--The distances between aircraft and foxes were not recorded for the encounters observed.

Two of four red foxes observed during an aerial survey of bird populations ran in response to the aircraft's approach (Schweinsburg, 1974a).

Of 15 arctic foxes sighted by aircraft surveying bird populations, only 1 took notice of the aircraft (Schweinsburg, 1974a). This fox took cover inside its den.

Snow Geese--The lateral distances at which 100 percent of the snow geese flushed in reaction to fixed-wing aircraft is provided as a function of aircraft altitude in Table 3.1.2.15-10 (Salter and Davis, 1974). There was no significant difference between the reaction of geese to aircraft as a function of flock size.

Canadian Geese--Canadian geese were observed to flush in response to fixed-wing aircraft flying one-half mile away at an altitude of 5,000 feet (Campbell and Shepard, 1973, as cited in Jacobson, 1974).

R. Schmidt (personal communication, as cited in Jacobson, 1974) observed that the geese were flushed during prenesting studies by fixed-wing aircraft traveling at altitudes of 200 to 500 feet, but that females located

Table 3.1.2.15-10 Distances at which all snow geese flush in response to Cessna 185 fixed-wing aircraft

ALTITUDE (ft)	LATERAL DISTANCE (mi)	DIAGONAL DISTANCE (ft)
300-400	1-5	26,403
700	2-9	47,525
1,000	2-4	21,144
5,000	2-5	26,869
7,000	as aircraft approaches or is above	6,000
10,000	as aircraft approaches or is above	10,000

near an airstrip would rarely flush even for aircraft as low as 50 to 100 feet.

Eggs in nests which were temporarily deserted in response to helicopter disturbances, were subjected to attacks by parasitic birds such as jaegers and herring gulls (R. Schmidt, personal communication, as cited in Jacobson, 1974).

Waterfowl--Moulting waterfowl (primarily oldsquaw and scoters) reacted mildly (swam further from shore and/or evidenced restlessness) to aircraft at distances of one-half to 1 mile away, before the aircraft was visible (Gollop, Goldsberry et al, 1974b).

The reaction of waterfowl to aircraft appears to be dependent on the size of the body of water. At a small lake, the waterfowl was reduced by 60 percent in response to aircraft disturbance, whereas on a medium-sized lake no change in population size was observed (Schweinsburg, 1974b).

The waterfowl population of two lakes (one used as a float plane base for 2-1/2 months prior to the investigation and the other was nearby) took little notice of the arrival and departure of aircraft, indicating the ability of some arctic loons, red-necked grebes, and scaups to adapt to float plane activity (Schweinsburg et al, 1974).

Lapland Longspurs--Subjecting nesting longspurs to an average of two helicopter flights per day at an altitude of 50 feet appeared to decrease fledgling production and population turnover rate and to forestall the onset of breeding activity (Gollop, Davis et al, 1974). The effects of aircraft disturbances at greater distances have not been investigated.

Gollop, Davis et al (1974) suggest that aircraft disturbances may delay the selection of otherwise optimal nesting sites and thereby reduce the productivity of these sites.

Lapland longspurs, as well as golden plovers, eventually abandoned areas near Churchill, Manitoba, indicating that long-term disturbances may lead to desertion of traditional habitats (Jehl and Smith, 1970, as cited in Gollop, Davis et al, 1974).

Black Brant--Black brant have been observed to flush in response to aircraft flying at distances of 1 to 2 miles away (Einarsen, 1965). One out of two incubating brants flushed when helicopters flew by at altitudes of 500 feet or less (Gollop, Black et al, 1974).

Helicopter disturbances when coupled with human disturbances may lead to a decrease in nesting success (Gollop, Black et al, 1974).

Common Eider--Incubating eiders did not flush in response to rotary or fixed-wing aircraft flying at altitudes as low as 20 feet, whereas non-nesting eiders flushed in response to helicopters at altitudes up to 3,000 feet (Gollop, Black et al, 1974).

Arctic Tern--Non-incubating and incubating terns were observed to flush in response to fixed-wing and rotary aircraft flying at altitudes up to 1,000 and 500 feet, respectively (Gollop, Black et al, 1974). Terns may take flight in reaction to fixed-wing aircraft flying at altitudes higher than 500 feet; altitudes above 500 feet were not studied.

Helicopter and human disturbances combined may result in a higher nest abandonment rate and a lower hatching rate (Gollop, Black et al, 1974).

Birds of Prey--No data are available concerning the distances at which birds of prey are disturbed by aircraft.

Hancock (1966) noted the reaction of bald eagles to helicopters used to survey their egg productivity in 1964. It was necessary to circle low over the nests to flush incubating eagles and the eagles would return immediately to the nest when the helicopter left. In 1965, the nests which had been surveyed by helicopter in 1964 had a 50-percent reduction in the number of young produced when compared to nests which had not been surveyed by helicopter in 1964. Normally, only 15 percent of eagle nests used in 1 year are abandoned in the subsequent year; 45 percent of the nests surveyed by helicopter in 1964 were abandoned in 1965.

Hancock (1966) reported that bald eagles do not flush as often in response to float planes as to helicopters nor as often to helicopters maintaining a straight course of flight as to helicopters which circle the nest. Einarsen (1965) observed that bald eagles only turned their heads to keep in sight an aircraft flown parallel to their perch altitude (300 feet).

With respect to golden eagles, Hickman (1972) reported that "incubating eagles could not be flushed, even with repeated passes, from the nests during aerial flights." Boeker and Bolen (1972) observed that golden eagles would flush only in response to aircraft which passed by in close proximity to their perches.

Campbell and Davies (1973, as cited in Jacobson, 1974) commented that whereas helicopters elicit strong responses from peregrine falcons, there is some evidence that falcons at traditional sites can adapt to overflights by aircraft.

Gyrfalcons are disturbed by helicopters flying nearby over their nests, but gyrfalcons rarely flush in reaction to similar fixed-wing aircraft flights (F. Beebe, personal communication, as cited in Jacobson, 1974).

Air Cushion Vehicles (ACV)

These vehicles will be utilized to transport the necessary equipment to a site requiring repair. The sound levels of this vehicle when cruising at 40 to 45 mph are presented in Table 3.1.2.15-11. The maximum distances at which birds have been observed to flush in response to this vehicle are listed in Table 3.1.2.15-12 (Slaney & Co., 1973b). Reactions of mammals to ACV have not been investigated.

Black brant evidenced increasing sensitivity to disturbance by ACV. The first flushing occurred at 750 feet, the next at 1,200 feet, and the third at 3,900 feet.

3.1.2.16 Hazards from Pipe Failure

The possibility of loss and damage due to pipe rupture is discussed in the Overview Volume.

Table 3.1.2.15-11 Air cushion vehicle (ACV) sound levels*

Location	Sound Level (dBA)
on ACV deck	106
150 ft. from ACV	98
500 ft. from ACV	87
4,200 ft. from ACV	60

* ACV was cruising at 40 to 45 mph.

Table 3.1.2.15-12 Maximum horizontal distance at which birds flush in reaction to air cushion vehicle noise

Bird	Estimated Maximum Horizontal Flushing Distance (ft.)
Greater Scaup	3,960
Black Brant	3,900
Whistling Swan	1,416
White-Fronted Goose	750*
Glaucous Gull	601*
Dabbling Ducks	273

* Average flushing distances

REFERENCES

Alaskan Arctic Gas Company Limited and Canadian Arctic Gas Study Limited, 1974, Interim report--slope stability in permafrost terrain (draft): prepared by Northern Engineering Services Co. Ltd., 117 pp. and appendix.

Banfield, A. W. F., 1974, The mammals of Canada: Univ. of Toronto Press, 438 pp.

Barney, R. J., and Comiskey, A. L., 1973, Wildfires and thunderstorms on Alaska's North Slope: USDA Forest Res. Note - PNW - 121.

Barry, T.W., 1967, Geese of the Anderson River Delta, N.W.T.: Ph.D. Thesis, University of Alberta, Edmonton, 212 pp.

Barry, T. W., and Spencer, R., 1971, Wildlife responses to oil well drilling: Can. Wildl. Serv. Rept., Edmonton, 39 pp.

Bliss, L. C., Courtin, G. M., Pattie, D. L., Riewe, R. R., Whitfield, D. W. A., and Widden, P., 1973, Arctic Tundra Ecosystems: Ann. Rev. Ecol. and Syst. 4:359-399.

Bliss, L. C. and Peterson, E. B., 1973, The ecological impact of northern petroleum development: Paper no. 6, 5th Internat. Cong. "Arctic Oil and Gas: Problems and Possibilities." Fondation d'Etudes Nordiques, Le Havre, 26 pp.

Bliss, L. C., and Wein, R. W., 1972, Ecological problems associated with arctic oil and gas development, p. 65-77, in Legget, R. F., and Macfarlane, I. C. (eds.), Proc. Can. N. Pipeline Res. Conf.: NRCC Tech. Memo. 104, Ottawa, 331 pp.

Boeker, E.L., and Bolen, E.B., 1972. "Winter golden eagle populations in the southwest," J. of Wildlife Management, Vol. 36.

Brown, Jerry, Rickard, Warren, and Vietor, Donald, 1969, The effect of disturbance on permafrost terrain: U.S. Army Material Command Cold Regions Research and Engineering Spec. Rept. 38, 13 pp.

Bugbee, S. L., and Walter, C. M., 1973, The response of macroinvertebrates to gasoline pollution in a mountain stream: Proc. Joint Conf. on Prevention and Control of Oil Spills, March 13-15, 1973, Washington, D. C., Am. Petroleum Inst., Environmental Protection Agency and U.S. Coast Guard, pp. 725-731.

Bugbee, S. L., Walter, C. M., and Lorenz, T. F., 1974, Salt River Oil Spill - An assessment of damages to the benthic community: Seattle, Wash., 37th Ann. Mtg. Am. Soc. Limnology and Oceanography, Inc., Abs. unpaged.

Cade, T. J., 1960, Ecology of the peregrine and gyrfalcon population in Alaska: Univ. Calif. Publ. in Zoology, v. 63, no. 3, pp. 151-290.

Calef, G. W., 1974, The predicted effect of the Canadian Arctic gas pipeline project on the Porcupine caribou herd, Chapt. 5 in Research Reports, Vol. IV, Environmental impact assessment of the portion of the Mackenzie gas pipeline from Alaska to Alberta: Environment Protection Board, Winnipeg.

Campbell, R.W., and Davies, B., 1973. "Nesting raptor survey in the Western Canadian Arctic, 1972," *Towards an Environmental Impact Assessment of the Portion of the Mackenzie Gas Pipeline from Alaska to Alberta: Interim Report No. 3*, Environment Protection Board, Winnipeg, Manitoba.

Campbell, R.W., and Shepard, M.G., 1973. "Spring waterfowl migration on the Mackenzie River from Norman Wells to Arctic Red River, N.W.T., 1972," *Towards an Environmental Impact Assessment of the Portion of the Mackenzie Gas Pipeline from Alaska to Alberta: Interim Report No. 3*, Environment Protection Board, Winnipeg, Manitoba.

Canadian Arctic Gas Pipeline Ltd., 1974a, Geotechnical Section, 8.b.1.3.7 (Geothermal analyses) *in* Location, Design and Capacity of Facilities: Canadian Arctic Gas Pipeline, Ltd., Sec. 8.

Canadian Arctic Gas Pipeline Limited, 1974b, Environmental statement, Canada north of the 60th parallel (section 14.s N): Exhibit in support of applications to the Department of Indian Affairs and Northern Development of the Government of Canada and the National Energy Board of the Government of Canada.

Canadian Arctic Gas Pipeline Limited, 1974c, Environmental statement, Canada south of the 60th parallel (section 14.d S): Exhibit in support of applications to the Department of Indian Affairs and Northern Development of the Government of Canada and the National Energy Board of the Government of Canada.

Canadian Arctic Gas Pipeline Limited, 1974d, Responses to Pipeline Application Assessment Group requests for supplementary information: Exhibit in support of applications to the Department of Indian Affairs and Northern Development of the Government of Canada for authorization to use land and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities; prepared by Northern Engineering Services Company Limited, chapters individually paginated.

Canadian Arctic Gas Pipeline Limited, 1975a, Amendments to alignment sheets (section 8.a.3, pipeline routing in the vicinity of Fort Simpson), and design drawings (section 8.b.3, for certain major river crossings), unpaged.

Canadian Arctic Gas Pipeline Limited, 1975b, Location of facilities (section 8.a), design and capacity of facilities (section 8.b), construction plan (section 13.a), and environmental statement (section 14.d): Exhibits in support of an amendment to applications to relocate the mainline near Ft. Simpson and to dual certain river crossings; sections individually paginated.

Carey, K. L., 1973, Icings developed from surface water and ground water: U.S. Army Material Command Cold Regions Research and Engineering Lab. Mon. III-D3, 71 pp.

Chekotillo, A.M., Tsuid, A.A., and MacKarov, V.N., 1960, Icings in the U.S.S.R. and their control; Amur Publishing House, Blagoveshohensk (Transl. from Russian), 148 p.

Crandell, F.J., 1949. "Ground Vibration Due to Blasting and Its Effect Upon Structures," Boston Society of Civil Engineers, Vol. 36, No. 2.

Crockett, J.H.A., 1963. "Traffic Vibration Damage in Medieval Cathedrals," Proceedings, RILEM, Budapest, Vol. I.

DeBock, E. A., and Surrendi, D., 1974, Some aspects of the ecology of the Porcupine caribou herd: Prelim Rept. prepared for the Task Force on Northern Oil Development, Ottawa.

Department of Indian Affairs and Northern Development, 1972, Expanded Guidelines for Northern Pipelines: No. 72-3, 34 p.

de Wit, R., Gronberg, E. C., Richards, W. B., and Richmond, W. D., 1973, Tathlina area, southern district of Mackenzie, p. 187-212, in McCrossan, R. G., (ed.), Future Petroleum Province of Canada: Canadian Soc. Petroleum Geologists Mem. 1, 720 pp.

Doll, D., McCrory, W.P., and Feist, J.D., 1974. "Observations of moose, wolf, and grizzly bear in the Northern Yukon Territory," Studies of Large Mammal Populations in Northern Alaska, Yukon and Northwest Territories, 1973, edited by K.H. McCourt and L.P. Horstman, Arctic Gas Biological Report Series, Vol. 22, Chap. 3, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co.

The Economic Staff Group, Dept. of Indian Affairs and Northern Development, and MPS Associates, Ltd., 1973, Regional impact of a northern gas pipeline, Volume 1 - Summary report: Task Force on Northern Oil Development, Report No. 73-28.

The Economic Staff Group, Dept. of Indian Affairs and Northern Development, and MPS Associates, Ltd., 1974, Volume 6 - Impact of pipelines on territorial population, labour force, employment and income (wages): Task Force on Northern Oil Development, Report No. 73-33.

Edwards, R. Y., 1954, Fire and the decline of a mountain caribou herd: J. Wildl. Manage., v. 18, no. 4, pp. 521-556.

Einarsen, A., 1965. Black Brant, Sea Goose of the Pacific Coast, Univ. of Washington Press, Seattle, Wash.

Environment Protection Board, 1974, Environmental impact assessment of the portion of the Mackenzie gas pipeline from Alaska to Alberta, Volumes I-IV. Environment Protection Board, Winnipeg.

Feist, J.D., McCrory, W.P., and Russell, H.J., 1974. "Distribution of Dall sheep in the Mount Goodenough area, Northwest Territories," Studies of Large Mammal Populations in Northern Alaska, Yukon and Northwest Territories, 1973, edited by K.H. McCourt and L.P. Horstman, Artic Gas Biological Report Series, Vol. 22, Chap. 2, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co.

Ferrians, O. J., Jr., Kachadoorian, Reuben, and Green, G. W., 1969, Permafrost and related engineering problems in Alaska: U.S. Geol. Survey Prof. Paper 678, 37 pp.

Freeman, M. M. R., 1971, Population characteristics of musk-oxen in the Jones Sound region of the Northwest Territories: J. Wildl. Manage., v. 35, no. 1, pp. 103-108.

Fyfe, R. W., and Kemper, J. B., 1974, Endangered raptor breeding territories near the proposed Mackenzie Valley gas pipeline route and recommendations for their protection: Prelim. rept. prepared for the Task Force on Northern Oil Development, Ottawa.

Geist, V., 1971, Is big game harrassment harmful?: Oilweek (Calgary), v. 22, no. 17, pp. 12-13.

Gemini North, Ltd., 1974, Social and economic impact of proposed Arctic Gas Pipeline in northern Canada: Books 1, 2, 3, 4.

Ghiglione, A.F., 1948, Highways, bridges and protection from ice damage: Alaska Road Commission rept., 10 p.

Gollop, M.A., Black, J.E., Felske, B.E. and Davis, R.A. 1974. "Disturbance studies of breeding black brant, common eiders, glaucous gulls and arctic terns at Nanaluk Spit and Philips Bay, Yukon Territory, July, 1972," Disturbance to Birds by Gas Compressor Noise Simulators, Aircraft and Human Activity in the Mackenzie Valley and the North Slope, 1972, edited by W.W.H. Gunn and J.A. Livingston, Arctic Gas Biological Report Series, Vol. 14, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co.

Gollop, M. A., and Davis, R. A., 1974, Gas compressor noise simulator disturbance to snow geese, Komakuk Beach, Yukon Territory, September, 1972: in Biol. Rept. Ser., Vol. 14, Chapt. VIII, prepared for Canadian Arctic Gas Study Ltd.

Gollop, M.A., Davis, R.A., Prevett, J.P., and Felske, B.E. 1974. "Disturbance studies of terrestrial breeding bird populations: Firth River, Yukon Territory, June, 1972," Disturbance to Birds by Gas Compressor Noise Simulators, Aircraft and Human Activity in the Mackenzie Valley and the North Slope, 1972, edited by W.W.H. Gunn and J.A. Livingston, Arctic Gas Biological Report Series, Vol. 14, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co.

Gollop, M.A., Goldsberry, J.R., and Davis, R.A. 1974a. "Effects of gas compressor noise simulator disturbance to terrestrial breeding birds, Babbage River, Yukon Territory, June, 1972," Disturbance to Birds by Gas Compressor Noise Simulators, Aircraft and Human Activity in the Mackenzie Valley and the North Slope, 1972, edited by W.W.H. Gunn and J.A. Livingston, Arctic Gas Biological Report Series, Vol. 14, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co.

Gollop, M.A., Goldsberry, J.R., and Davis, R.A. 1974b. "Aircraft disturbance to moulting sea ducks, Herschel Island, Yukon Territory, August, 1972," Disturbance to Birds by Gas Compressor Noise Simulators, Aircraft and Human Activity in the Mackenzie Valley and the North Slope, 1972, edited by W.H.H. Gunn and J.A. Livingston, Arctic Gas Biological Report Series, Vol. 14, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co.

Gordon, R. C., 1972, Winter survival of fecal indicator bacteria in a subarctic Alaskan river: Corvallis, Oreg., U.S. Environmental Protection Agency, National Environmental Research Center, Project 1600 FHB, Program Element 1B2044 (EPA-R2-72-013), 39 pp.

Government of Alberta, 1969, Atlas of Alberta; Edmonton, Alberta Univ. Press, 162 pp.

Grainge, J.W., Edwards, R., Heuchert, K.R., Shaw, J.W., 1973, "Management of Waste from Arctic and Sub Arctic Work Camps," Northern Pipelines, Task Force on Northern Oil Development Report No. 73-19, Information Canada Cat. No. R72-10173.

Gray, D.R. 1971. "Winter research on the muskoxen (Ovibos moschatus wardi) on Bathurst Island, 1970-71," Arctic Circle, Vol. 21, No. 3.

Hancock, D. 1966. "David Hancock reports on the bald eagle research project," Canadian Audubon, Vol. 28.

Harder, A. H., Whitman, H. M., and Rogers, S. M., 1965, Methane in the fresh-water aquifers of southwestern Louisiana and theoretical explosion hazards: Dept. of Conservation, Louisiana Geol. Survey, Water Resources Pamphlet 14, 22 pp.

Hendron, A.J., and Oriard, L.L. 1972. "Specifications for Controlled Blasting in Civil Engineering Projects," Proceedings of the 1st North American Rapid Excavation and Tunneling Conference, Chicago, Illinois, June.

Herbert, R.A., and Herbert, K.G.S. 1969. "The interpretation of the Hudson River peregrine falcon population," The Peregrine Falcon: Their Biology and Decline, Univ. Wisc. Press, Madison, Wisc.

Hernandez, H., 1974, Possible effects on vegetation of the proposed gas pipeline from Prudhoe Bay, Alaska and the Mackenzie Delta to Alberta, pp. 37-69, in Research Reports, v. IV, Environment impact assessment of the portion of the Mackenzie gas pipeline from Alaska to Alberta: Environment Protection Board, Winnipeg.

Hickman, G.L. 1972. "Aerial determination of golden eagle nesting status," J. of Wildlife Management, Vol. 36.

Howard, C.D.D., 1974, Mackenzie Gas Pipeline, Alaska to Alberta--Effects on the aquatic physical environment. Pages 177-202 in Research Reports, Vol. IV of Environmental impact assessment of the portion of the Mackenzie gas pipeline from Alaska to Alberta: Environment Protection Board, Winnipeg, Manitoba.

How, G.T.S., 1974, Effects on the terrain of the construction and operation of proposed Mackenzie gas pipeline project. Pages 1-28 in Research Reports, Vol. IV of Environmental impact assessment of the portion of the Mackenzie gas pipeline from Alaska to Alberta: Environment Protection Board, Winnipeg, Manitoba.

Ingraham, R., 1970, From the edge of extinction; p. 13, in Ingraham, R., (ed.), Endangered wildlife in Canada: Can. Wildl. Federation, Ottawa, 15 pp.

Jacobson, J.O., 1974, Potential impact of the Mackenzie gas pipeline on bird populations in the Yukon and Northwest Territories, Chapt. 6, in Research Reports, Vol. IV, Environmental impact assessment of the portion of the Mackenzie gas pipeline from Alaska to Alberta: Environment Protection Board, Winnipeg.

Jakimchuk, R.D., DeBock, E.A., Russell, H.J., and Semechuk, G.R. 1974. "A study of the Porcupine caribou herd," The Porcupine Caribou Herd--Canada, edited by R.D. Jakimchuk, Arctic Gas Biological Report Series, Vol. IV, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co.

Jehl, J.R., Jr., and Smith, B.A. 1970. Birds of the Churchill region, Manitoba. Manitoba Museum of Man and Nature (Winnipeg). Spec. Publ. No. 1.

Johnston, G. H., 1969, Dykes on permafrost, Kelsey generating station, Manitoba: Canadian Geotech. Jour., v. 6, no. 2, pp. 139-157.

Kelsall, J. P., Hawley, V. D., and Thomas, D. C., 1971, Distribution and abundance of musk-oxen north of Great Bear Lake: Arctic, v. 24, no. 3. pp. 157-161.

Klein, D.R. 1973. "The reaction of some northern mammals to aircraft disturbance," 11th International Congress of Game Biologists; Stockholm, Sweden.

Kucera, Emil, 1974, Potential effects of the Canadian arctic gas pipeline on the mammals of western Arctic; Chapt. 4 in Research Reports, Vol. IV, Environmental impact assessment of the portion of the Mackenzie gas pipeline from Alaska to Alberta: Environment Protection Board, Winnipeg.

Lenarz, M. 1974. "The reaction of Dall sheep to an FH-1100 Helicopter," The Reaction of Some Mammals to Aircraft and Compressor Station Noise Disturbance, edited by R.D. Jakimchuk, Arctic Gas Biological Report Series, Vol. 23, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co.

Lent, P. C., 1971, Muskox management controversies in North America: Biol. Conserv., v. 3, no. 4, pp. 255-263.

Lent, P.C., and Summerfield, R., 1973. "Population dynamics and seasonal movement patterns of Dall sheep in the Atigun River Canyon," Alaska Cooperative Wildlife Research Unit Monthly Report, August, U. of Alaska, Alaska.

Leopold, A. S., and Darling, F. F., 1953, Effects of land use on moose and caribou in Alaska: Trans. N. Am. Wildl. Conf. 18, pp. 553-562.

Lewellen, Robert and Brown, Jerry, 1969, Man-induced erosion of permafrost: Preprint of paper submitted to 20th Alaska Science Conf., College, Alaska.

Linderman, S., 1972. "A report on the sheep study on the Dietrich River headwaters," Sheep Segment Report, Alaska Dept. of Fish and Game, Juneau.

Macpherson, A. H., 1965, The barren-ground grizzly bear and its survival in northern Canada: Can. Audubon Mag., Jan-Feb. 1965, pp. 2-7.

McCourt, K.H., Feist, J.D., Doll, D., and Russell, J.J., 1974, Disturbance studies of caribou and other mammals in the Yukon and Alaska, 1972: Biol. Rept. Ser. Vol. 5, Renewable Resources Consulting Services Ltd., for Canadian Arctic Gas Study Ltd. and Alaskan Arctic Gas Study Co., 246 pp.

McCourt, K.H., and Horstman, L.P. 1974. "The reaction of barren-ground caribou to aircraft," The Reaction of Some Mammals to Aircraft and Compressor Station Noise Disturbance, edited by R.D. Jakimchuk, Arctic Gas Biological Report Series, Vol. 23, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co.

McCoy, G. A., 1974, Preconstruction assessment of biological quality of the Chena and Little Chena Rivers in the vicinity of the Chena Lakes flood control project near Fairbanks, Alaska: Anchorage, Ak., U.S. Geol. Survey Water-Resources Inv. 29-74, 84 pp.

McKee, J. E., and Wolf, H. W., 1963, Water quality criteria, 2d ed.: The Resources Agency of California, California Water Quality Control Board Pub. 3-A, 548 pp.

Mech, L.D. 1970. The Wolf: The Ecology and Behaviour of an Endangered Species, The Natural History Press, Garden City, N.Y.

Millar, J. F. V., 1974, Proposal for archeological salvage, pipeline corridor, Yukon and Northwest Territories: Archaeological Supplement to the Biological Report Series, Canadian Arctic Gas Study, Ltd., 2nd ed., unpaged.

Nauman, J. W., and Kernodle, D. R. (in press), The effect of a fuel oil spill on benthic invertebrates and water quality on the Alaskan Arctic Slope, Happy Valley Creek near Sagwon, Alaska: Jour. of Research of the U. S. Geol. Survey.

New York State Department of Environmental Conservation, "Construction Noise Survey." April 1974.

Nichols, D. R., and Yehle, L. A., 1961, Highway construction and maintenance problems in permafrost regions: Proc. 12th Ann. Symposium on Geology as Applied to Highway Engineering, Bull. 24, pp. 19-27.

Northern Engineering Services Company, Limited, 1974a. Inuvik snow road construction, testing and environmental assessment 1973-1974, Inuvik N.W.T.; Canada. 90 pp. and appendix.

Northern Engineering Services Company, Limited, 1974b. Inuvik snow road, environmental assessment. 13 pp. and appendix.

Ohtake, Taheshi, 1970, Studies on ice fog: National Center for Air Pollution Control, Admin. Report.

Peterson, R. L., 1955, North American moose: Univ. Toronto Press, Toronto, 280 pp.

Pipeline Application Assessment Group, 1974, Mackenzie Valley pipeline assessment environmental and socio-economic effects of the proposed Canadian Arctic gas pipeline on the Northwest Territories and Yukon: Minister of Indian Affairs and Northern Development, (Information Canada), Ottawa, 442 p.

Prescott, W.H., Erickson, G.L., Walton, L.E. and Smith, D. G., 1973, Atlas of moose habitat maps: Can. Wild. Res. Ser., Edmonton, Alberta.

Quick, H. F., 1953, Wolverine, fisher and marten sutdies in a wilderness region: Trans. N. Am. Wildl. Conf. 18, pp. 513-533.

Quimby, R. 1974. "Grizzly bear," Mammal Studies in Northeastern Alaska with Emphasis within the Canning River Drainage, edited by R.D. Jakimchuk, Arctic Gas Biological Report Series, Vol. 24, Chap. 2, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co.

Quimby, R., and Snarski, D. J., 1974, A study of furbearing mammals associated with gas pipeline routes in Alaska; in Jakimchuk, R. D., (ed.), Distribution of moose, sheep, muskox and furbearing mammals in northeastern Alaska: Arctic Gas Biol. Rept. Ser. v.6, Canadian Arctic Gas Study Ltd., Calgary (in press).

Reynolds, P.C. 1974. "The effects of simulated compressor station sounds on Dall sheep using mineral licks on the Brooks Range, Alaska," The Reaction of Some Mammals to Aircraft and Compressor Station Noise Disturbance, edited by R.D. Jakimchuk, Arctic Gas Biological Report Series, Vol. 23, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co.

Richards, J. H., and Fung, K.I., 1969, Atlas of Saskatchewan: Saskatoon, University of Saskatchewan, 236 pp.

Roseneau, D.G., and Warbelow, C. 1974. "Distribution and numbers of muskoxen in Northeastern Alaska and the Northern Yukon, 1973," Studies of Large Mammal Populations in Northern Alaska, Yukon and Northwest Territories, 1973, edited by K.H. McCourt and L.P. Horstman, Arctic Gas Biological Report Series, Vol. 22, Chap. 2, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co.

Ruttan, R.A. 1974a. "Observations of moose in the Northern Yukon Territory and Mackenzie River Valley, 1972," Studies of Furbearers Associated with Proposed Pipeline Routes in the Yukon and Northwest Territories, edited by R.A. Ruttan and D.R. Wooley, Arctic Gas Biological Report Series, Vol. 9, Chap. 6, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co.

Ruttan, R.A. 1974b. "Observations of grizzly bear in the Northern Yukon Territory and Mackenzie River Valley, 1972," Studies of Furbearers Associated with Proposed Pipeline Routes in the Yukon and Northwest Territories, edited by R.A. Ruttan and D.R. Wooley, Arctic Gas Biological Report Series, Vol. 9, Chap. 7, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co.

Salter, R., and Davis, R.A. 1974. "Snow geese disturbance by aircraft on the North Slope, September, 1972," Disturbance to Birds by Gas Compressor Noise Simulators, Aircraft and Human Activity in the Mackenzie Valley and the North Slope, 1972, edited by W.W.H. Gunn and J.A. Livingston, Arctic Gas Biological Report Series, Vol. 14, Canadian Arctic Gas Study, Ltd., and Alaskan Gas Study Co.

Schweinsburg, R.E. 1974a. An Ornithological Study of Proposed Gas Pipeline Routes in Alaska, Yukon Territory and the Northwest Territories, 1971, Arctic Gas Biological Report Series, Vol. 10, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas and Study Co.

Schweinsburg, R.E., 1974b. "Disturbance effects of aircraft to waterfowl on North Slope Lakes, June, 1972," Disturbance to Birds by Gas Compressor Noise Simulators, Aircraft and Human Activity in the Mackenzie Valley and the North Slope, 1972, edited by W.W.H. Gunn and J.A. Livingston, Arctic Gas Biological Report Series, Vol. 14, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co.

Schweinsburg, R. E., 1974c, Snow geese disturbance by aircraft on the North Slope, September, 1972: Biol. Rept. Ser. Vol. 14, Chapt. VII, prepared for Canadian Arctic Gas Study Ltd.

Schweinsburg, R.E., Gollop, M.A., and Davis, M.A. 1974. "Preliminary waterfowl disturbance studies, Mackenzie Valley, August, 1972," Disturbance to Birds by Gas Compressor Noise Simulators, Aircraft and Human Activity in the Mackenzie Valley and the North Slope, 1972, edited by W.W.H. Gunn and J.A. Livingston, Arctic Gas Biological Report

Series, Vol. 14, Canadian Arctic Gas Study, Ltd., and Alaskan Arctic Gas Study Co.

Skoog, R. O., 1968, Ecology of the caribou (Rangifer tarandus granti) in Alaska: Univ. California Berkeley, unpub. Ph.D. thesis.

Slaney, F.F., and Company, Ltd. 1973a. "Wildlife," Interim Report 1972 Environmental Field Program Taglu Richards Island, Mackenzie Delta, Part III, Imperial Oil Ltd., Calgary.

Slaney, F.F., & Company, Ltd. 1973b. Environmental effects assessment--Voyageur air cushion vehicle MacKenzie Delta, N.W.T., Vol. II, Field Studies, Environmental Protection Service, Ottawa, Ontario, Canada.

Soliman, J.I., 1973. "Criteria for Permissible Levels of Industrial Vibrations with Regard to Their Effect on Human Beings and Buildings," Proceedings, RILEM, Budapest, Vol. 1.

Spencer, D. L., and Lensink, C. J., 1970, The muskox of Nunivak Island, Alaska: J. Wildl. Manage., v. 34, no. 1, pp. 1-15.

Stecher, P. G., (ed.), 1968, The Merck Index: Rahway, N. J., Merck and Co., Inc., 1713 pp.

Steffens, R.J., 1966, Some Aspects of Structural Vibration," Symposium, Vibration in Civil Engineering, London.

Summerfield, B.L. 1974. "Population dynamics and seasonal movement patterns of Dall sheep in the Atigun Canyon Area, Brooks Range, Alaska," unpublished Master's thesis, U. of Alaska, Fairbanks, Alaska.

Tener, J. S., 1965, Muskoxen in Canada--a biological and taxonomic review: Queen's Printer, Ottawa, Ont., 166 pp.

Thomson, S., 1963, Icings on the Alaska Highway, p. 526-529 in Proc. Int. Conf. Permafrost. Lafayette. Indiana: Natl. Acad. Sci. - Natl. Res. Counc., Washington, D.C. 563 p.

U. S. Department of the Interior, 1972, Evaluation of Environmental Impact, v. 4 of Final Environmental Impact Statement, Proposed Trans-Alaska Pipeline: Springfield Va., Natl. Tech. Inf. Service, PB-206 921-4, 637 pp.

U.S. Environmental Protection Agency. 1972. "Noise from Construction Equipment and Operations," NTID 300.1.

U.S. Environmental Protection Agency. 1973. "Public Health and Welfare Criteria for Noise," Document 550/9-73-002, July.

Watmore, T. G., 1969, Thermal erosion problems in pipelining in Brown, R. J. E., Proceedings of the Third Canadian Conference on Permafrost, Ottawa: Natl. Research Council Canada, Tech. Memo. 69, pp. 142-162.

Watson, G.H., Prescott, W.H., de Bock, E.A., Nolan, J.W., Dennington, M.C., Poston, H.J., and Stirling, I.G., 1973, An inventory of wildlife habitat of the Mackenzie Valley and the Northern Yukon. Environ. - Social Com. Northern Pipelines. Task Force on Northern Oil Development Rep. No. 73-27. Dept. Environment, Edmonton, Alberta. 152 p.

Wein, R. W., and Bliss, L. C., 1973, Biological considerations for construction in the Canadian permafrost region, paper no. 6, Mackenzie Delta reigon, pp. 767-770, in Permafrost: The North American Contribution to the Second International Conference: Natl. Acad. Sc., Washington, D. C.

Zhigunov, P. S., (ed.), 1968, Reindeer husbandry: (trans. from Russian), Israel Program for Scientific Translation, Jerusalem.

4 MITIGATING MEASURES INCLUDED IN THE PROPOSED ACTION

4.1 ARCTIC GAS PIPELINE PROJECT

4.1.2 Canadian Pipeline

For purposes of this Statement, mitigating measures are those provisions concerning the proposed action that would lessen or eliminate adverse environmental impacts resulting from construction and operation of the proposed pipeline system.

It is possible for mitigating measures to be devised and implemented by either the Applicant or the Government. Mitigating measures on the part of the Applicant would generally be design features or construction, operation and maintenance rules specifically formulated to protect the environment. Mitigating measures on the part of the Government would generally be stipulations, also specifically formulated to protect the environment.

The measures that the Applicant would use to mitigate environmental impacts are set forth in documents submitted to the Governments of the United States and Canada (CAGPL, 1974, Section 14.d N, 14.d S). The first three sections of this part of the Statement reproduce the Applicant's environmental protection plans insofar as they can be discerned in the submittal documents. No other procedure would seem to convey intent as clearly.

As has been noted, the Government's role in formulating, adopting and enforcing explicit environmental and technical stipulations is fundamental in mitigating environmental impact. The posture of the Government of Canada may be discernable in the "Expanded Guidelines for Northern Pipelines" that were introduced in the House of Commons on June 28, 1972 (CAGPL, 1974, 14.d N, section 2.2, p. 5). These guidelines are reproduced in the fourth section of this part of the Statement because no other procedure so clearly conveys what the Government's intent may be. Reproducing the guidelines however, does not certify that they are adequate and correct or that they will be adopted and enforced.

Analysis and evaluation of the Applicant's mitigating measures show that most, if not all, components of the ecosystem that could be affected have been identified. Exactly what mitigating countermeasures the Applicant would take are less fully specified, however. For example, in considering unstable slopes that might be encountered, the Applicant promises to develop "Designs ... to cope with any unstable situation." (CAGPL, 1974 14.d N., 6.3.2). Or similarly, in connection with stream crossings, it intends that "Freedom of passage for fish will be ensured during construction activities ..." (CAGPL, 1974, 14.d N., 6.3.4). These statements of good intent are not accompanied by design details that would allow predictions of the likelihood of stabilizing slopes or assuring unrestricted passage of fish.

No analysis of proposed mitigating measures can be adequate without an evaluation of the role of the Government in formulating and enforcing stipulations or other legal measures that would minimize environmental impact. Such evaluation is doubly difficult in the case of a Canadian pipeline because the environmental stipulations and codes to which pipelines are constructed in the United States are not enforceable in Canada. Moreover, it is not appropriate for this Statement, prepared in fulfillment of a law of the United States, to query the environmental objectives, concerns or intentions of Canada. It is assumed that the citizens of Canada and the Government that represents them are as concerned for the protection of their environment as is the United States for its own. More critical appraisals of mitigating measures, as applied to the United States, are given in the portions of this Statement concerning the Alaska, Northern Border, and West Coast segments of the proposed gas transmission system.

The "Expanded Guidelines for Northern Pipelines," as reproduced in this report, are proposals only, and not stipulations, codes or laws presently in force. Like the Applicant's proposed mitigating measures, the "Expanded Guidelines" seem to accurately identify most, if not all, areas of special concern in the ecosystem through which the pipeline would pass. Thus if put into law as presently formulated, with one very important exception, the "Expanded Guidelines" would provide an adequate legal basis for requiring generally acceptable environmental practices in construction and operation of the proposed pipeline system.

The important exception is in specifying what the Government will require of itself. Governmental inspectors and monitors comprise the essential linkage between mitigating design provisions and environmentally oriented construction and operation procedures on the one hand, and stipulations, codes and laws that are the basis of requiring good environmental practice on the other hand. The "Expanded Guidelines" do not reveal whether or not the Government of Canada will develop and field an adequate inspecting and monitoring staff to determine if construction and operation performances meet high environmental standards.

4.1.2.1 Measures to Protect the Environment as Proposed by Applicant

The Applicant's "Environmental Statements" (CAGPL, 1974, 14.d N and 14.d.S) list measures that would be used by the Applicant to mitigate adverse environmental effects that might result from constructing and operating the proposed pipeline. Among other things the procedures envisioned include: 1) education of personnel involved in construction and operation, 2) construction timetables planned to prevent permanent damage to various components of the ecosystem, 3) design features and construction procedures specially formulated for permafrost terrain, 4) monitoring procedures to detect unforeseen changes in environmental quality, 5) plans for clean-up and restoration, and 6) maintenance and contingency plans.

Many design features of the proposed system would differ according to whether their location would be north or south of 60° N. latitude. Latitude 60° N is the northern boundary of British Columbia and Alberta--both self-governing provinces--and the southern boundary of the Yukon and Northwest Territories administered by the Department of Indian Affairs and Northern Development. The parallel is also the approximate southern limit of the zone of discontinuous permafrost. Like the design features of the proposed system, the mitigating measures differ somewhat according to location, and have been drawn up separately by the Applicant. Both sections are reproduced in the following pages.

The two sections that follow contain references to design features or construction procedures in the Applicant's sections 8 (Location, Design and Capacity of Facilities) and 13 (Construction Plan and Operations and Maintenance Plans). Sections 8 and 13 together amount to more than 600 printed pages and are not, therefore, reproduced in this Statement. In general, however, the design details to which the references pertain are summarized in section 1.1.2 of this Statement (Description of the Proposed Action).

The following section is quoted from Environmental Statement (Canada - North of the 60th Parallel), Section 14.d N, Canadian Arctic Gas Pipeline Ltd, 1974:

6.0 Measures to Protect the Environment

The Applicant's efforts to protect the environment along the pipeline route began at the inception of project planning. At that time, the nature of biotic and other components of the environment were known in a general way; extensive studies have subsequently revealed what conditions will be encountered, what potential problems might arise and what concerns require special attention.

Measures to protect the environment include the shaping of initial planning and design, the education of personnel involved in construction and operations, and the enforcement of environmental regulations. Continuing studies will further improve the understanding of the natural setting.

Although this Subsection 6 is included in the discussion of the environment north of 60 degrees N, and some portions of it relate solely to that area, the bulk of this discussion is also applicable to the rest of the Applicant's pipeline system south of 60 degrees N.

Most construction north of 60 degrees N (and well south of that point) will be carried out during the winter months. During this period, the frozen terrain is least susceptible to damage from construction traffic; migratory birds are wintering in southern areas; fish are concentrated in lakes or large river over-wintering areas; migratory caribou are in their southern wintering range; and other animal activity is at a low level.

Access during construction will be primarily along the pipeline right-of-way on temporary snow and ice roads.

6.1 Education, Monitoring and Enforcement

6.1.1 Education

The Applicant will provide an environmental education program for pipeline construction personnel from management through to the field worker. This program will instruct such personnel on basic concepts of ecology and northern environments. The major objectives of the education program are:

1) to reduce worker-caused environmental damage, such as fires, wildlife harassment and littering, and
2) to encourage worker-solution of unforeseen environmental problems.

There will be various levels of environmental education according to the worker's responsibility or his potential for causing environmental change in the normal course of his duties. For example, construction workers engaged in preconstruction activities such as clearing, surveying or stockpiling will require more specialized training to prevent undue damage from their activities. Those in supervisory positions, including engineers and foremen, will have to make decisions in the field with regard to environmental problems.

The Applicant will have environmental inspection personnel on each construction spread whose responsibility it will be to ensure that the principles and procedures transmitted in the education program are followed and that all activities are carried out in compliance with relative regulations and guidelines and the Applicant's policy to minimize disturbance. Such inspectors will co-ordinate their work with government inspectors in the field.

Environmental Education Guidelines

The following guidelines will be paramount in the development of a program of environmental education.

1) The effectiveness of any training program is dependent upon a firm commitment by management. The Applicant's management accepts environmental training as a part of its responsibilities and will provide for it in the corporate organization.

2) Such training will be integrated with environmental inspection, and there will be liaison between inspectors and the educators so that the training program is continually upgraded.

3) All project personnel will receive environmental training, and the Applicant will also require outside supply and service personnel to take such training.

4) As the potential for environmental damage varies with the job description and the level of responsibility, so must the level of the education be varied (Table 6.1-1).

5) An environmental training program will be formulated for each of the personnel classifications and will begin with the training of the Applicant's and the contractor's management and the supply and logistics teams.

6) The environmental education program will be field-oriented and directed by professionals in the relevant disciplines.

7) As many unforeseen sources of environmental change will arise as construction gets underway, the training program will be flexible to accommodate these changes.

8) The environmental training program will be integrated with other training programs such as those for heavy equipment operators.

The following subject areas are typical of those which will be required in the environmental education program:

1) aspects of the northern environment
2) environmental concerns in general construction
3) worker behaviour which will reduce environmental damage

Upon completion of the construction phase, there will be a continuing staff for operation and maintenance of the pipeline. It is probable that many of these employees will have had previous experience in the construction phase. With their employment as permanent operators of the pipeline, however, there will be new requirements for environmental training. Suitable and continual environmental training will be provided so that there will be minimal disruption to the environment as a result of operation. In addition, however, one would expect a valuable contribution to the monitoring of wildlife and habitat along the pipeline as a result of observations of trained and interested personnel.

6.1.2 Monitoring and Enforcement

The purpose of the environmental monitoring and enforcement program is to insure that the environmental recommendations and specifications developed by the Applicant are put into practice. At the same time, the program will assure compliance with applicable government regulations. The results of environmental baseline and experimental research have been integrated

TABLE 6.1–1

Potential for damage rating for construction workers by job classification

CLASSIFICATION	ASSUMED TO INCLUDE	ENVIRONMENTAL DAMAGE POTENTIAL
Foreman	All supervisory personnel, general superintendents, assistant superintendents, engineers, all classes of foremen	High for all personnel
Welder	Stringer, hot pass, fill and cap, tie-in, utility structural	Low for all personnel
Journeyman	Pipefitter, spacer, stabber, and end prop. operator	Low for all personnel
Operator	All classifications and rates under the jurisdiction of operating engineers, except apprentices	High for dozer, grader, drag-line, backhoe, etc. operators; low for operators of tapers, sidebooms, etc.
Mechanic	Light and heavy duty mechanic, serviceman, fuelman, greaseman	Low except for disposal of used motors oils, fuel handler, etc.
Tradesman (skilled labour)	Electrician, carpenter, iron worker, technician, driller, blaster, powerman, cook	Low except for blaster
Teamster	Heavy duty driver, warehouseman, yardman, material handler	Low except for fuel oil and chemical material handler
Apprentice	Apprentice to any trade, oiler	Variable, depending on duty
Semiskilled	Helper, rodman, chainman, power saw operator, paper latcher, fireman, bull cook, filer	Generally low
Unskilled	Common labour, skid hustler, swamper, axeman, crumber	Low for all personnel
Support	Pilots, barge operators, medical personnel, fire crews, caterers	Low except for pilots and barge operators

with project engineering design, and the approach to enforcement is basically the same as the engineering approach to supervision of construction and operation.

- *Construction Phase*

Environmental Inspectors will be assigned to each construction spread and staging site, and to other areas of associated activities and will report through appropriate channels to the Applicant's senior management. The foremost responsibility of the Environmental Inspector will be to supervise implementation at the construction sites of measures to protect the environment. They will inspect activities on a continuing basis. Measures for environmental protection form a part of the pipeline design and will be written into construction specifications. The Environmental Inspectors will ensure compliance with these specifications and with government regulations.

They will be required to work closely with the engineering inspectors and must have knowledge of the construction operation, as well as an understanding of environmental matters, that will enable them to interpret environmental concerns into specific construction directions as applicable. They will provide liaison between the construction contractors and the government environmental inspectors. Their qualifications will include a broad knowledge of the northern environment, an understanding of the Northerners' use of the environment and the capability to make judgments and decisions in the field. The Environmental Inspectors, through their superiors, will have authority to shut down such field operations as may contravene company or government environmental regulations.

- *Operation Phase*

The operational phase of the pipeline project will require a different environmental input than will the construction phase. Enforcement of environmental policies will be concerned primarily with operating procedures, and personnel needs will be fewer due to a less intensive level of activity.

The responsibility of monitoring and enforcement personnel during operation will be twofold: continued research and facilities inspection. Research will be conducted to evaluate the success of special techniques used during construction to protect the environment. It will also be important to ensure that no new environmental problems develop from operation of the line and its appurtenant facilities.

i) Post-Construction Research - The environmental research conducted prior to construction will provide the information base from which to measure the impact of the pipeline project. The monitoring programs outlined below are designed to detect changes in the environment which may develop over a period of time as a result of the Applicant's project. Such information is important not only to indicate the need for changes in operation and maintenance but also to provide a basis for forecasting the impact of future expansions of this project or the initiation of projects similar in nature. Examples of these programs are: determination of the long - and short-term effects of aircraft disturbance on species of waterfowl, ungulates and furbearers; determination of the impact of man's presence on various wildlife and fish species; determination of the effects of various vehicles and construction equipment on vegetation; and evaluation of the environmental suitability of various pipeline construction techniques.

ii) Facilities Inspection - Inspection of pipeline facilities from the environmental viewpoint will be made on a regular basis. These inspections will be similar to and scheduled with the inspection conducted during normal pipeline maintenance. The inspection will include checks of both the pipeline right-of-way and the compressor station sites, as well as other facilities associated with the Applicants' project. Inspection will include checks on drainage and erosion, surveillance and maintenance of revegetation, monitoring of gaseous emissions at compressor sites, and control of chemicals or potential pollutants.

In addition to conducting routine inspections, environmental personnel will be responsible for ensuring that operating and maintenance personnel comply with both external and internal environmental regulations. These cover a broad spectrum from ensuring that game regulations are followed to advising on heights for aircraft line patrol.

6.2 Further Studies

Continuing environmental studies, to enable the Applicant to make continual modifications of detailed planning where necessary, include:

1) continued monitoring of barren ground caribou, other mammals and fish,
2) continued reading of the established bird sites,
3) further disturbance studies of birds,
4) monitoring of Arctic test facilities,
5) a program to increase the supply of native grasses and to ensure an adequate supply of agronomic species and to monitor sites where revegetation has been accomplished,
6) an intensive program of monitoring birds, fish, mammals and vegetation at Chick Lake, together with surface and subsurface drainage studies and
7) studies on slope stability, stabilization measures, drainage and erosion control measures and frost effects.

6.3 Specific Environmental Measures

The basic criterion used in developing environmental protection measures was to change the natural environment as little as possible. The following specific actions reflect the Applicant's approach.

6.3.1 General

1) The installation of pipe will be largely carried out during the winter season, both to avoid terrain damage and because this measure also significantly reduces any interaction between construction spreads and fish and wildlife.

2) Neither insecticides nor herbicides will be used north of 60 degrees. Other substances used during the construction and operation of the pipeline, such as pipe coating materials, lubricating materials, flushing agents, and possibly pipe-testing solutions, will receive special care in transportation, storage, and disposal.

3) Gas leaks, should they occur after the pipeline is in service, will be detected by operating personnel in the right-of-way surveillance procedures. Repairs to such leaks would be made immediately.

4) Line breaks, if any, when the pipeline is in service would be detected by flow and pressure monitoring devices. Valve closures would then ensure the isolation of the ruptured section. Special repair contingency plans would go into immediate effect.

5) Firearms will be prohibited in construction camps except for one rifle provided to the camp manager. No employees or agents of the Applicant or contractors will be permitted to hunt, fish or trap from any camp area. This policy will apply similarly to operations and compressor station sites.

6) All construction waste and surplus materials will be removed from the right-of-way and other areas used for staging, access, or work space and returned to designated storage areas. Incinerator residue will be buried in approved sites.

7) Aircraft altitude, flight-path and scheduling will be strictly controlled to minimize disturbance

to wildlife, especially to snow geese, raptors, bears, sheep, musk-ox and caribou.

8.) The pipeline has been designed so that large capacity initially will be built into the Prudhoe Bay and Richards Island laterals. This measure reduces the need for further pipeline construction (looping) in later years.

6.3.2 Terrain and Vegetation

1) The Applicant's geological studies show that the route as chosen crosses no faults along which recent movement is known or believed to have occurred.

2) Potentially unstable slopes have been identified and were circumvented in the pipeline alignment.

3) A method has been developed for analyzing the stability of thawing slopes.

4) Prior to final design, slopes which are suspected of possible instability upon thawing, particularly at river crossings, will receive additional field investigation and laboratory testing of samples. Designs will be developed to cope with any unstable situation.

5) Chilling of the gas during operation will prevent degradation of permafrost around the pipe.

6) Snow roads will be constructed to provide a protective work and travel surface, where necessary, along the right-of-way or any access not served by permanent roads. Ice bridges used in stream crossings will be removed (along with debris, if any) prior to spring breakup.

7) Revegetation and/or other erosion control measures will be promptly implemented to restore soil stability and vegetation damaged or destroyed by the Applicant. Tundra will be removed, where beneficial, prior to ditching and replaced after backfill in order to assist revegetation. Mixes of native and agronomic grass species will be used in seeding programs. On sites where seeding alone may not be sufficient, other techniques such as the planting of shrubs, protective matting, or rip rap will be used.

8) Where instability of native ditch backfill is suspected such as on slopes containing ice-rich materials, it is proposed to use select stabilizing backfill.

9) Clearing of trees will be done so as to leave the roots and ground cover as intact as possible, thereby reducing erosion and permafrost degradation. Bulldozers (used in winter clearing) will be equipped, where necessary, with special "shoes" on the blade in order to prevent cutting into the organic mat. Any summer clearing in sensitive terrain areas will be done by hand.

10) Disposition of cut trees and slash will, unless otherwise directed by the authorites, be by winter burning over the ditch line.

11) Forest and tundra fires are unlikely during winter construction activities. Contingency fire-fighting plans will be be developed for the construction and operation phases in cooperation with the appropriate local authorities.

12) The selection of borrow sources is dependent upon terrain sensitivity, timing of borrow operations, effect of noise and traffic, effect upon water quality and regime, use of the area by fish and wildlife, and upon borrow requirement studies. Borrow pits in low-lying wet areas will

be reclaimed to provide new wetland habitat. Shape of the pit, side slopes, revegetation, and islands will be considered in this respect. Other borrow pits will be suitably restored.

13) The possibility of differential settlement of the pipe in discontinuous permafrost areas south of the chilled gas operation is remote and can be further reduced by deeper burial.

14) After pipe installation, a program of right-of-way surveillance will be promptly implemented. The main purpose of this surveillance is early detection of signs of erosion, slope instability, or any other potential threat to the system or the environment. The frequency of such surveillance will vary with the season and could be as often as weekly during spring breakup or periods of high fire potential.

6.3.3 Air

1) The fuel (natural gas) used by compressor stations will be clean burning. The combustion product will have no more than a trace of sulphur compounds and nitrogen oxide.

2) Combustible waste will be burned in high temperature incinerators to ensure complete combustion and minimization of particulate emissions.

3) Compressor stations that must be located in areas where normal noise levels might unduly disturb wildlife will be equipped with sound suppression devices that will reduce such localized disturbance.

6.3.4 Water

1) Large quantities of water will be required for such purposes as ice roads, pressure testing, ditch flooding, and camps. In selecting water sources, care will be taken to ensure that its removal will not seriously impair important aquatic habitat. Compressor stations will not require water during operations except for minor domestic and industrial use.

2) The extraction of granular materials from the inactive floodplain of rivers will be necessary in some areas. Special precautions will be taken to limit siltation and ensure that no serious alteration of the normal river course occurs. The free passage of fish will be ensured.

3) In both permafrost and non-permafrost terrain, run-off flows upstream of the pipeline right-of-way will be intercepted, by low diversion dikes and shallow ditches diverted across the backfill mound through gravel protected breaks, and discharged into the undisturbed area on the downslope side. Existing microdrainage systems will be maintained by allowing both surface and subsurface flows to pass over the ditch line and through the backfill, in addition to providing protected mound breaks.

4) Major river and stream crossing sites were studied from aerial photos and from the air by helicopter. Subsequent ground surveys of these sites included river bed surveys, exploratory drilling, and soil testing. Scour depth, sag points, and pipeline profile across the main rivers were established to ensure safe operation of the pipeline.

5) The pipeline route avoids crossings of ponds or lakes or unnecessary close proximity to streams and shorelines. In addition, the alignment and location of facilities has been chosen to avoid areas where bank recession due to thermokarst, natural land-wasting, or other processes cannot be controlled within tolerable limits.

6) Addition of sediments into streams during run-off will be reduced by control of drainage on and across the right-of-way. The use of selected materials, revegetation or erosion control mats, and drainage controls will prevent surficial erosion and gullying and minimize the flow of sediments downslope into rivers and streams.

7) Oils and greases for construction equipment will be carefully handled to prevent their entry into watercourses. Procedures will be established and facilities provided for safe storage of unused materials and for the proper disposal of all waste fluids.

8) Disposal of liquid test medium will be carried out in a manner and in locations that will not endanger aquatic habitat. Solutions of methanol, should they be used,will be reused and then distilled, with the methanol held for reuse or burned.

9) Sewage from camps or compressor stations will receive secondary treatment. The treated effluent will be released to a lagoon with capacity for storage of one year's inflow.

6.3.5 Fish

1) Scheduling of pipeline construction activities will, where possible, minimize the interference with fish populations. Large river crossings may be installed in summer or winter. Smaller crossings will be installed during winter when most are frozen to bottom.

2) At most river and stream crossings, the pipeline will be laid beneath the stream bed, leaving no permanent obstructions in the channel and requiring only temporary disruption to the stream bed. Where river beds are disturbed by pipeline construction, restoration using stabilized materials will be carried out.

3) Freedom of passage for fish will be ensured during construction activities in stream or river beds and in the location, design, and maintenance of culverts associated with access roads.

6.3.6 Birds

1) The location of all facilities was chosen to avoid unnecessary conflict with bird habitat and populations. The coastal route in particular was located inshore as much as possible, within other constraints of terrain and wildlife, in order to reduce conflict with shore birds and moulting sea ducks. A major route change in the Travaillant Lake area reduced conflict with important bird wetland habitat and a rare and endangered species nest.

2) Raptor sites have been identified and avoided in facilities locations.

3) Moulting areas have been identified and avoided.

4) Sound muffling of compressor stations in sensitive coastal areas will reduce unavoidable disturbance to snow geese.

5) Construction activities along the coastal route right-of-way will not start until waterfowl staging is completed. Similarly, work on the right-of-way will be ended prior to the birds' return in the spring.

6) Aircraft altitude, flight-path and scheduling will be strictly controlled to avoid or reduce disturbance to birds, especially snow geese and raptors.

7) Barges will remain one to ten miles offshore.

6.3.7 Mammals

1) Construction of the pipeline during the winter season will virtually eliminate interaction with caribou (Porcupine herd) during all phases of the animal's life cycle. Herds will be kept under surveillance during this period to warn of any unexpected occurrence that would require contingency measures. The installed pipeline and its right-of-way will not interfere with wildlife movements as the pipe will be fully buried, and studies have shown that the right-of-way will not in itself adversely affect caribou migration.

2) Major concentrations of furbearers have been identified and avoided in route location. Special drainage control measures have been designed to maintain natural drainage patterns to and from wetland areas on either side of the right-of-way.

3) Denning sites of grizzly bears, Arctic foxes, and wolves have been avoided in original route planning; sites which subsequently become known will be avoided during construction by minor field changes in alignment as required.

4) Winter range of moose and Dall sheep has been identified and largely avoided in route location.

5) Garbage disposal methods to be implemented during construction and operation phases will reduce the attraction of bears and foxes.

6) Reindeer herders will be consulted in order to minimize adverse disturbance of their herding activities during construction.

7) Deliberate or inadvertent aircraft and ground vehicle harassment of wildlife will be minimized during construction and operation through controls on flight plans (direction and ceiling) and vehicle use.

8) Fences will be built around those airstrips where concentrations of caribou could occur.

6.3.8 Archaeological Sites

1) Potentially productive archaeological sections and locations have been identified along the route and classified as being high, medium or low priority.

2) Archaeological survey of selected high priority sections and localities will be carried out ahead of construction activities either before or accompanying preliminary surveys or preparation activities. Archaeological crews will accompany ditching and other construction or excavation activities to provide surveillance of any archaeological sites exposed at that time.

3) Sites discovered before construction will be avoided wherever possible or, when practical, will be salvaged in advance of construction.

4) Sites discovered, but not otherwise affected by construction, will be clearly marked and identified for future investigations.

5) Sites discovered during ditching or other excavation will be flagged and salvaged where

possible.

6) The importance and identification of artifacts will be included in the environmental training program for construction personnel. Procedures for reporting discoveries to archaeologists will be implemented.

7) The Applicant will arrange that the artifacts will be deposited in appropriate public repositories and expects that most will be placed in suitable northern museums.

6.3.9 Aesthetics

The drawings and accompanying statements which follow set forth principles which the Applicant will follow to achieve aesthetically desirable results. Specific principles of aesthetic concern will be applied to situations encountered along the right-of-way. These principles are intended to indicate the attitude and response toward typical situations, involving visual consideration, which can be expected throughout the route. They do not necessarily relate to any specific physiographic region.

These steps will be taken even though much of the study area will remain remote from extensive visitation for the foreseeable future. Special care will be taken to minimize the immediate visual impact in areas of anticipated contact (i.e. roads, major rivers, communities).

6.4 Application of Environmental Measures

Many of the environmental protective measures listed in Subsections 6.1 through 6.3, above, have already been incorporated into the Applicant's design and planning. In some cases, this was done on the basis of original planning by engineering staff and consultants and management. In many cases, however, such measures were adopted after extensive consultation between such personnel and environmental consultants and staff. (See Section 8.a for several examples which in total involves many miles of pipeline rerouting to improve the environmental aspects of the line).

The Applicant plans to continue such consultation and utilization of the skills of environmental disciplines, as described above, so that the environmental protective measures will continue to be utilized during the pre-construction preparation, construction and operating phases of the pipeline life.

6.5 Abandonment

Governmental guidelines indicate a desire that the Applicant comment upon the steps to be taken upon abandonment of a pipeline. This is difficult to do realistically at this time, however, both because the conditions at that time cannot be known, but even more importantly, because that time will be so far distant. In light of the huge potential reserves of gas in the Canadian and Alaskan Arctic, it is certain that the Applicant's pipeline, once installed, will be operative for many decades. The gas reserves should last that long, and the physical life of the pipeline, especially given modern construction and maintenance methods, should be longer. Already, one transmission line in Alberta has been in service for over 60 years. It is important to remember that natural gas is not only an energy source, but also a vital petrochemical building block.

When abandonment becomes an issue decades from now, there are a variety of possible alternatives. For example:

- The pipe in the ground could be left in place. Succession of vegetative growth would continue on the right-of-way and eventually even the relatively minor visual evidence of the pipeline would disappear. The line would be in stable surrounding soil and would remain "frozen in" in permafrost soil.

- Surface facilities which were not found to be desirable for continued human use would be removed and salvaged. The remaining sites would be restored and returned to nature or turned to other human uses. (An example is that communication facilities could be put to other uses. However, they too could be removed if newer technology had become available and made them obsolete by that time.)

The following section is quoted from Environmental Statement (Canada - South of the 60th Parallel), Section 14.d S, Canadian Arctic Gas Pipeline Ltd, 1974:

16.0 Project Measures to Protect the Environment

16.1 General

An effective environmental protection program is based on an adequate knowledge of the environment, procedures for minimizing adverse impact, a personnel education program which ensures that protective measures are understood and an inspection system to ensure that they are used.

Procedures for minimizing environmental impact have been developed by the Applicant and by other pipeline companies and are applicable to the Applicant's pipeline system. Some of these measures have been described in Section 14.d.6.

As to knowledge of the specific environment along the pipeline route south of 60 degrees N, particular environmental studies conducted by the Applicant have been noted. The area is also well-known to biologists, is discussed in the literature and supports several resource development projects. In addition, the Applicant intends to supplement such knowledge by further specific preconstruction programs beginning in 1974.

Mammal studies will further determine the location and relative importance of wildlife habitat along the proposed route, with emphasis on northern Alberta. Fisheries studies will entail reconnaissance surveys of streams and rivers crossed by the route. Further data will be gathered on species present, habitat conditions, and the relative productivity of particular watercourses. Ornithological research will further determine areas of concentration for birds during migration, nesting and moulting along the pipeline route. Vegetation studies will be designed to inventory the major plant communities along the pipeline route south of 60 degrees N. An important aspect of this work will be detailed examination of key sites on existing pipelines which the proposed pipeline will closely parallel. Sites which will be studied in detail, to obtain first hand experience in order to develop appropriate programs for avoiding or correcting problem situations, will include areas of slope instability and wind or water erosion.

In the area of personnel education, the Applicant will conduct an environmental education program for all groups of project personnel from management to field labourers.

Finally, environmental inspectors will monitor project activities to ensure that protection measures are applied and to provide advice on problems requiring field decisions.

Subsections 16.2 through 16.11, below, contain a listing of some environmental protective measures which will be applied.

16.2 Terrain and Vegetation

1. Hand clearing methods will be used where mechanical methods would be more harmful to the environment, such as on steep slopes and stream banks.

2. In permafrost areas, slash will normally be burned over the ditch line. If suitable slash burning sites cannot be located where permafrost or organic terrain will not be damaged, burning sleds will be used.

3. Native and agronomic grasses will be used to control erosion on disturbed sites in non-cultivated areas.

4. Mechanical surface and ditch stabilization techniques will be used where required to supplement erosion control by revegetation methods.

5. Regular inspection of the right-of-way will detect soil movement, gullying and ponding on the right-of-way and will enable maintenance crews to undertake reseeding, drainage or other necessary measures to prevent terrain damage.

Additional measures to prevent terrain damage are contained in Section 14.d.16.5 following and Section 8.b.

16.3 Water

1. The pipeline and related facilities will be designed to protect the quality and natural movement of surface and subsurface water. Measures to protect water resources are included in Section 16.5 following and Section 8.b.

16.4 Air

1. The fuel (natural gas) used by compressor stations will be clean burning. The combustion product will have no more than a trace of sulphur compounds and nitrogen oxide. Compressor station emission will be within the standards laid down by Provincial and Federal authorities.

2. Combustible waste will be burned in high temperature incinerators to ensure complete combustion and reduction of particulate emissions.

3. Compressor stations that must be located where normal noise levels might unduly disturb wildlife will be equipped with sound suppression devices that will reduce such localized disturbance.

16.5 Fish

1. Close parallels with streams and lake shores will be avoided and, wherever feasible, a minimum 1/4-mile buffer strip will be left to serve as a sediment trap.

2. Where stream crossings must be made in the vicinity of critical areas, the timing of construction will be such as to minimize damaging effects. In general, for spring spawning populations (pike, walleye, longnose sucker, etc.) fall and winter crossings are preferred, and for all spawning populations (whitefish, ciscoe, etc.) spring and summer crossings are preferred.

3. Materials will not be removed from active flood plains.

4. To prevent erosion, crossing sites will be chosen to ensure maximum bank and substrate stability.

5. Revegetation will prevent erosion of road margins and other disturbed areas. Ditch blocks, water guides and other facilities may be necessary to channel water away from disturbed areas and into surrounding vegetation.

6. Sewage treatment plants will be used where domestic sewage is produced. Effluent will be ponded during winter months where necessary.

7. Fertilizer, fuels and all other chemicals will be stored away from water bodies, in diked compounds, to minimize the effects of accidental spillage on aquatic life.

8. Following hot water line pressure tests, the water will be reoxygenated, if necessary, by spraying.

9. Only those water sources approved by government authorities will be used by the project and will also be examined by project biologists to determine the influence on aquatic life and to recommend measures to eliminate adverse effects.

10. Where culverts on access roads are required, these culverts will be designed so that fish migration will not be hindered.

16.6 Birds

1. Lakes which are less important to bird species will be used to meet project water transportation, construction, domestic and other requirements.

2. Major moulting, breeding, staging, and other critical areas will be identified and avoided to prevent undue disturbance to birds.

3. Aircraft altitude, flight-path and scheduling will be strictly controlled to avoid or reduce disturbance to birds.

4. Possession of firearms by construction personnel will be prohibited.

5. Indiscriminate use of snowmobiles by project personnel will be prohibited.

6. Insecticides will not be used on the project.

7. Height of communication towers will be held to a minimum consistent with good communication.

8. Areas frequented by bald eagles and other rare and endangered species along the route will be avoided, particularly during the nesting season. Disturbance to the larger areas surrounding nest sites will be minimized. Disturbance of nests or adult birds will be strictly prohibited.

9. The pipeline route will, where possible, be located a suitable distance from important bird habitat such as wetland and habitat remnants.

16.7 Mammals

1. Winter construction in northern Alberta will prevent conflict with fawning caribou in late May and early June.

2. Large carnivore den sites will be identified and care taken to avoid disturbance or destruction.

3. Normal drainage patterns will be maintained on the right-of-way, to avoid disturbance of aquatic mammal habitat.

4. Deliberate or inadvertent aircraft and ground vehicle harassment of wildlife will be minimized during construction and operation through controls on flight plans (direction and ceiling) and vehicle use.

5. Possession of firearms by employees and other persons retained by the Applicant will be prohibited.

6. High temperature incinerators will be used for combustible garbage and landfills for non-combustible wastes.

7. Precautions will be taken to avoid compressor station disturbance of critical ungulate winter range or fawning/lambing/calving grounds.

16.8 Forestry

1. In forested areas, every precaution will be taken to ensure that fires do not occur. Comprehensive contingency plans, trained personnel and necessary equipment will be available to control any fires that do occur.

2. Erosion control, maintenance of natural drainage patterns and other protection measures will assure minimal environmental change, and the continuance of natural growing conditions in forested areas adjacent to the right-of-way.

16.9 Agriculture

1. In cultivated areas, topsoil will be removed from the ditch, piled separately and returned to the ditch crown following installation.

2. The pipeline crown, borrow sites and other disturbed areas, except in cultivated areas, will be revegetated. Either native grass species or agronomic species will be used.

3. Precautions will be taken to avoid disturbance of domestic livestock during both construction and operation phases.

16.10 Recreation

1. Environmental protection measures outlined above will minimize impact on recreational resources and assure maintenance of existing outdoor recreation opportunities.

2. Recreational use of project vehicles will be prohibited during the construction and operation phases.

3. Construction will be carried out during the winter months on the portion of the pipeline north of Caroline, thereby greatly reducing potential conflict with outdoor recreation activity.

16.11 Archaeology

A plan has been developed to inventory archaeological sites along the proposed pipeline route, at facility locations and at other areas to be disturbed by project activity as follows:

1. The archaeological potential of sections of the route has been determined and classified as

being high, medium or low priority.

2. Archaeological survey of selected high and medium priority sections or localities will be carried out ahead of construction activities, either before or accompanying preliminary surveys or preparation activities. Archaeological crews will accompany ditching and other construction activities to provide surveillance of archaeological sites exposed at that time.

3. Sites discovered before construction will be avoided wherever possible or, when practical, will be salvaged in advance of construction.

4. Sites discovered, but not otherwise affected by construction will be recorded and clearly marked and identified for future investigations.

5. Sites discovered during ditching or other construction activities will be flagged and salvaged where possible.

6. The importance and identification of artifacts will be included in an environmental training program for construction personnel. Procedures for reporting discoveries to archaeologists will be implemented.

7. The Applicant will arrange that the artifacts will be deposited in appropriate public repositories.

4.1.2.2 Restoration as Proposed by Applicant

The restoration measures envisioned by the Applicant consist mainly of removing refuse from areas used during construction and revegetating the right-of-way and other land surfaces from which the natural plant cover was removed. Portions of the Applicant's construction plan (CAGPL, 1974, 13.a, p. 56-59) pertaining to these activities are reproduced on the following pages. In addition, some of the measures listed in the preceding section are restorative or conducive to restoration.

The following section is quoted from Construction Plan, Section 13.a, p. 56-59, Canadian Arctic Gas Pipeline Limited, 1974:

6.7 Clean-up

A. CONVENTIONAL WINTER CONSTRUCTION

All sites or rights-of-way used during any phase of construction, whether they are temporary or permanent in nature, will require clean-up. The clean-up will follow the completion of construction activity as closely as possible.

Waste Material

All surplus construction material will be collected and returned to the original construction stockpile points or to other designated storage areas. All waste construction material will be removed and disposed of at designated locations. Combustible waste will be burned. Other materials will be buried on the right-of-way, at stations or other facility sites or at abandoned borrow pits specified by the Applicant. All buried material will be covered with at least 24 inches of fill. All damaged or leaning trees will be felled, unless otherwise specified by the landowner or regulatory authority.

Fences

Where fences have been cut and temporary gates installed, the fences will be permanently repaired to the satisfaction of the landowner.

Roads

Public and private roads used or crossed during construction will be returned to a condition at least equal to their standard prior to construction. Temporary roads built for construction purposes will be cleaned up in accordance with the requirements of the landowner or regulatory authority.

Any clean-up work undertaken during winter will be subject to inspection when snow cover has disappeared in the following spring. Any additional clean-up required will be completed that summer, or the following winter, depending upon ground conditions.

B. ARCTIC CONSTRUCTION

The procedure for clean-up in the Arctic construction areas will be, in general, similar to A above. The differences will be:

1. Burning sites will be carefully chosen to avoid degradation of permafrost. If suitable sites are not available, burning sleds will be used. In some cases, slash will be burned over the ditch line.
2. In some areas, cleared brush from borrow areas and the pipeline right-of-way may be used as insulating fill or cover for restoration of borrow areas and the pipeline right-of-way respectively.
3. Abandoned borrow pits will be used as the preferred burial sites. If borrow pits are not available, care will be taken in selecting burial sites to avoid high ice content permafrost.
4. In some areas, select backfill material will be used in place of native spoil for purposes of buoyancy or erosion control. The resulting surplus spoil will be disposed of in borrow pits, or by spreading it on the right-of-way or by adding it to the ditch crown.

6.8 Restoration and Revegetation

In developing its construction procedures, the Applicant has concentrated on minimizing disturbance of terrain cover. Where construction of the pipeline necessarily requires that it be disturbed, the Applicant has established a program which is designed to restore the terrain to its previous condition and to ensure that environmental stability has been re-established.

In establishing its program, the Applicant:

(a) has employed and retained geotechnical experts, agronomists and botanists who have conducted an extensive review of the technical literature relating to restoration and revegetation and have consulted with representatives of governmental agencies and industry experienced in restoration and revegetation projects.
(b) has established test revegetation plots at its sites at Prudhoe Bay, Sans Sault and Norman Wells which it will continue to monitor, and
(c) has carried out revegetation projects over disturbed areas such as well sites.

Further, the Applicant has begun the accumulation of seed stocks of grasses suitable for revegetation.

A major purpose of the Applicant's restoration and revegetation program in all areas of the system is to establish equilibrium conditions whereby thermal or hydraulic erosion, ditch settlement, slope instability or any other type of degradation is eliminated or reduced. Such measures will meet two complementary objectives, namely:

(a) establishment of acceptable environmental conditions; and
(b) maintenance of the integrity of the operating pipeline.

A. CONVENTIONAL WINTER CONSTRUCTION

Pads and Roads

At those sites where permanent granular pads are built for use as compressor station sites, stockpile sites or airstrips, restoration and revegetation will be required around the boundaries of the sites. If these pads divert normal drainage patterns, then the restoration will ensure that such drainage is diverted around the pad in a manner which will prevent erosion.

Culverts will be installed under roads to channel water past the obstruction to natural drainage courses, thereby protecting the roads' embankments from erosion. Care will be taken in the installation and maintenance of culverts not to block the passage of fish.

In areas along the perimeters of pads and roads, vegetation will be re-established. In some areas, the natural revegetation processes will be sufficient. Where specified by the Applicant's consultants, a revegetation program will be undertaken using a combination of natural species and selected agronomic species which have proven suitable in test programs. Fertilizer will be applied at an optimum level to aid the revegetation process. Details of seed mixes are shown under terrain stability in Section 8.b. 1.3.

Borrow pits

For those borrow pits which have been exhausted or which will not be required for operating and maintenance purposes, restoration will be undertaken as soon as practicable following completion of construction. Stumps originally cleared from the site will be returned to it. Non-combustible debris cleaned up from the pipeline right-of-way or other construction sites may also be disposed of in the borrow pit. The debris will then be buried under burden material originally stripped from the pit.

Where the borrow pits have not filled with water, the cover material will be graded and contoured to eliminate any sharp relief. The complete borrow pit area will then be re-seeded and fertilized to provide a vegetation cover as quickly as possible.

Where the borrow pits have filled with water, contouring and re-seeding of cover material will be done around the banks to encourage their stabilization as soon as possible, thus producing a naturally stable lake.

Pipeline Right-of-way

The pipeline right-of-way will be restored to its original condition as completely as is practicable. Cuts for construction purposes will be graded to form safe and stable slopes. This will require placement of breakers, crossberms, terraces, and diversion ditches across the right-of-way to prevent the flow of water along the pipeline ditch and to maintain, to the extent possible, natural drainage patterns. Details of erosion control and slope stability design are shown in Section 8.b. 1.3.

In the first spring following construction, the right-of-way will be seeded and fertilized. Seed mixes to be used are also described in the section dealing with drainage and erosion control.

Aircraft will be utilized to seed the straight and relatively level portions of the pipeline. Other areas will require use of helicopters.

Ground crews will be used at hillsides, river crossings or other areas requiring the spreading of erosion control mats, the planting of shrub cuttings or the application of seed by hand. Materials will have been stockpiled during the winter at each of these areas in order to avoid vehicular travel on the right-of-way after snow melt.

All seeding and restoration will be under the management and direction of a senior. agrologist, with trained field supervisory personnel responsible for each construction spread. The completion, monitoring and continuing maintenance of the revegetation program will form part of the on-going responsibility of the Operations and Maintenance Department as described in Section 13.b, 5., Routine Operations and Maintenance.

B. ARCTIC CONSTRUCTION

In Arctic construction areas, the same general restoration and revegetation procedures will be followed, with the following modifications:

1. Erosion control devices will be constructed of excess spoil or borrow material placed on the ground surface without removal of the existing organic cover.
2. Where side hill cuts are required in permafrost, they may be made vertically, so that the resultant thaw and slumping over of the vegetative cover will produce a stable slope. This practice is in general use in highway construction in Alaska (Ref: Lotspeich, F.B., Environmental Guidelines for Road Construction in Alaska, Environmental Protection Agency Report 1060-GOI-OH/71, 1971). Where conditions are not appropriate for use of this method, conventional slope stabilization techniques as described in Section 8 b., 1.3 will be used.
3. Existing organic cover will be removed, stockpiled and replaced on the ditch line as a means of re-establishing native vegetative cover.
4. Special seed mixes will be employed.
5. Natural revegetation will be assisted and supplemented by a revegetation program specifically developed for use in Arctic areas.
6. Insulation mats may be used to insulate permafrost slopes.
7. In areas where settlement of frozen backfill has created actual or potential drainage or buoyancy problems, the ditch crown will be re-shaped and, if necessary, additional borrow will be added. This will be done as a follow-up to construction during the next winter season and as required during succeeding winters as an Operations and Maintenance function.

4.1.2.3 Emergency Measures as Proposed by Applicant

Many adverse environmental impacts, including some of potentially great duration, could result from the hasty marshalling of heavy equipment that would be occasioned by pipe rupture or other sudden, unforeseen interruption in transmission. Some impacts might be eliminated or diminished through the use of adequate and carefully prepared contingency plans. The Applicant's sketch of contingency plans that would be developed toward the end of the construction phase of the proposed project is quoted below (CAGPL, 1974, 13.b.,p. 26-33):

6.0 Upset and Contingency Repairs

6.1 Major Line Repairs

6.1.1 Major Line Repairs - General

In endeavoring to meet the consistent project objectives of maximum human safety, security and reliability of the pipeline system, and minimum disruption of the environment, the Applicant's planning process has sought the best available technology for location, design, construction and operation of the pipeline.

A part of such planning must consist of predetermined plans of action to be utilized in the unlikely event that a major line break is caused by events which cannot be specifically forecast in planning or anticipated under normal operating conditions. The following subsections describe in a general way the considerations and main courses of action which would be required in the case of a major line break.

6.1.2 Contingency Planning

No single emergency repair contingency plan can be developed for the entire pipeline because of the wide range of physical conditions encountered along the pipeline and the seasonal variation of these conditions. Accordingly, specific contingency plans for shorter sections of the line will be prepared: for example, a section of line running between two adjacent compressor stations. These sectional contingency plans will be based in each case on "as-built" information recorded on the Alignment Sheets set forth in separate Volumes submitted herewith. This information, compiled prior to and during construction, will consist of essential site-specific data including:

- final line route and profile referenced to survey markers and topographic features;
- location of access roads to right-of-way;
- location of facilities such as compressor stations, meter stations, camps, communications, mainline block valves, pipeline mileposts, airstrips and associated access roads;
- type of terrain, vegetation and subsurface soils encountered during construction;
- depth of line covers, types of backfill material and details of special construction provisions for road and water body crossings, erosion and buoyancy control, and revegetation of line cover;
- location and size of backfill material storage sites and borrow areas;
- hydrological data including local drainage patterns and the location of water bodies suitable for aircraft use; and
- referenced data sheets specifying local environmental concerns and related protective measures.

Each sectional contingency plan will be in the form of standing orders listing the manpower, materials and equipment needed to effect major line repairs of various magnitudes and sequential steps for their utilization to the extent required by a particular occurrence. Recorded data particular to each sectional plan could include:

- location and content of the equipment storage depot nearest to the line section and of the next adjacent storage depots;
- optimum routing and method of transportation of men and equipment from these depots to various points on the line section, having regard to different seasonal environmental constraints;
- lists of terrain protection mats, hand tools, light-weight equipment units, portable service, shelter and camp units, pre-packed and grouped for helicopter transport from the storage depot to the repair site;
- lists of the locations and quantities of pre-tested pipe lengths, heavy repair equipment units with loading and dispatch sequences for their transport by road haul units and/or low-ground-pressure units;
- schedules of the fuel supply requirements of the equipment to be used in the repair operations;
- lists of regional contractors outlining their capability of possible assistance in line repair procedures;
- lists of owners and occupants of lands traversed by the line section;
- lists of regional agents of government bodies (for example, land use and law enforcement) to be notified in emergency situations;
- identification of specific local human and environmental concerns and procedures for emergency use of land adjacent to the right-of-way;
- the site-specific data forming part of the Alignment Sheets;
- specific assignment of two senior supervisors from the District, one in charge of all operations at the repair site, and the other responsible for the logistics of the repair operation, including the mobilization, scheduling and dispatching of men, materials and equipment to the site, the reporting of progress to the Gas Control Centre, and the securing and co-ordinating of the activities of any contractors used in the repair;
- site arrangement plans which will specify the position and placement sequence of: terrain protection mats; temporary communications towers; portable camp units; shelters for work area, tools and materials; power generators and lighting standards; testing, air compression, pumping and fire extinguishing equipment; fuel storage units; and work equipment areas;
- schedules for the mobilization, dispatch, transport and working shift rotation of personnel from District (and, in an extreme case, from adjoining Districts) required to effect repairs of various magnitude;
- standby arrangements and notification procedures for any potential contracted supply of services.

The Applicant's contingency plans will always reflect the current status of any revisions to the pipeline and its operations, improvements in equipment technology, new structures and human activity within the particular area for which the plan is developed. The Applicant's operation and maintenance personnel will be kept familiar with contingency measures through scheduled training programs and through practice drills requiring response to simulated specific emergency situations.

The Applicant's standard operating plans will provide lists of minimum available manpower, equipment and supplies for each base location within the District. Daily work orders will record the assignment of personnel to locations other than their base location so that they may be dispatched to any location where they are required.

6.1.3 Transportation Considerations

As indicated in the earlier descriptions of ground and air transportation equipment, the transportation of men and equipment will be by existing all-weather roads to the extent possible and, to areas not so accessible, by aircraft in order to cause the least disturbance of sensitive terrain. These factors will be incorporated into sectional contingency plans for major line breaks. It is recognized, however, that a line break could occur in permafrost regions at a time when the active layer is unfrozen. This possibility was anticipated in the location and selection of the Applicant's equipment requirements described in Section 13.b.3.1, Ground Transportation and Work Equipment. Emergency transportation in soft terrain situations could be effected in the following manner:

(a) With the exception of pipelayers, backhoes, dozers and replacement pipe, all of the equipment required in a major line repair operation can be transported by helicopters.

(b) In regions not served by all-weather roads, there will be maintenance and repair equipment and materials stored at each compressor station site. The maximum distance of off-road transportation of heavy equipment will be from the closest depot of the required equipment to the repair site.

(c) The heaviest load which cannot be transported by any type of helicopter available at the present time is the chassis of a pipelayer. The low-ground-pressure transport units proposed for the pipeline can haul the chassis of the pipelayer with the ancillary equipment being hauled by helicopter or another low-ground-pressure vehicle.

(d) The air transportable equipment at each storage depot will include quantities of terrain protective mats, which would be placed on the repair sites when required to protect the ground surface from the effect of equipment manoeuvres. Modular pontoon sets used for temporary bridging of rivers and ponds can be similarly transported.

(e) The air-cushion vehicle to be based in Inuvik will be used, where applicable, in emergency situations within the Northern Division to transport heavy equipment over rivers in flood stage or in ice flow conditions.

6.1.4 Implementation of Contingency Plan

A break resulting in the escape of appreciable quantities of gas from the line will activate the valve operator on the mainline block valve in the affected section. The line break will be detectable from changes in the data shown on the continuously monitored system display console at the Gas Control Centre. These data will enable the Gas Control Centre personnel to identify the compressor station nearest to the point of break and to determine whether the break is upstream or downstream of this identified compressor station. Upon such detection, the pertinent specific contingency plan will be implemented through a sequence of events which could be as follows:

Initial Response

(a) The upstream and downstream stations will automatically shut down due to loss of suction or discharge pressure.

(b) The Gas Control Centre will take advantage of the presence of any personnel performing scheduled maintenance in the region of the line break, by directing them through the communications system to proceed to determine the specific location of the break and to take the initial steps of implementing the contingency plan as described in the following paragraphs.

(c) The Gas Control Centre will contact the District Superintendent in whose District the break has occurred, who will assume command of all contingency plan activities.

(d) The Gas Control Centre then will initiate procedures resulting in notification of:

- the Manager of the relevant Division, who will place the Districts adjoining that in which the break has occurred on standby mobilization;
- gas producers, users and shippers, who will prepare for possible curtailment of service; and
- agencies of government and other parties having a role or specific interest in emergency operations.

(e) The District Superintendent will use the communication system to alert the repair site supervisor and the support supervisor.

(f) The repair site supervisor will assemble a repair crew and proceed to the break site in order to secure the required positioning of mainline block valves and blowdown valves. This crew will travel by helicopter going firstly to the indicated compressor station site and thence along the right-of-way to the site of the line break. Continuous radio communication will be maintained with the District Superintendent and with any crew previously dispatched from nearby work locations.

(g) The support supervisor will place on standby alert all District personnel and others potentially involved in contingency plan operations and immediately dispatch to the designated equipment storage depot the personnel required to load and transport materials and equipment to the repair site. Where indicated by the sectional contingency plan, this initial movement of repair personnel from the operating bases to the remote equipment storage locations will be by aircraft. Similarly, if conditions indicate aircraft transportation of light equipment and materials to be the preferred method, the required aircraft will be dispatched from Division Headquarters to the designated equipment storage depot.

Assessment of Damage:

(a) On arrival at the line break, the repair supervisor will advise the District Superintendent of the specific location and nature of the break, the conditions at the site, and any urgent measures required to ensure the safety of humans and property in the region of the break.

(b) The site investigation crew will then make observations of the break site to determine the extent of damage to the line, the right-of-way and adjoining property, any apparent cause of the break, the presence of any surface water, and the local weather conditions. On the basis of this information communicated by the crew and the site-specific data of the sectional contingency plan, the District Superintendent will determine the extent to which the plan must be implemented to effect the repair and will instruct the support supervisor to continue with the mobilization and dispatch of the required personnel, equipment and materials.

(c) Following the assessment of damage, the repair site crew activities will include: reporting to the District Superintendent on the extent of any gas flow from the break; ensuring the closure of mainline block valves, the competence of line valve seal and the de-activation of valve operators; the opening of blowdown valves as required to hasten the depressurization of the damaged line segment; and the laying out of the repair site in anticipation of the arrival of repair equipment and materials.

Transportation of Manpower, Equipment and Materials

(a) When the District Superintendent has ascertained the required extent of implementation of the contingency plan, sufficient additional maintenance personnel will be dispatched to the designated equipment depot to man the first twelve-hour shift of repair operations. Since, in most cases, the designated equipment depot will be at the compressor station nearest to the break and will be accessible by all-weather road from a nearby airstrip, movement of manpower will be by aircraft whenever flying conditions are suitable. A second complete crew will be provided to permit repair operations to continue on an around-the-clock basis until the repair is completed.

(b) The repair materials and equipment will be dispatched from the depot in a sequence related to the order of their required use at the repair site, beginning with the terrain protective mats, any necessary repair site camp equipment including water supply and waste disposal units, and other air transportable equipment indicated by the specific contingency plan. This equipment will be taken to the repair site by helicopter. In the absence of suitable flying conditions, this equipment will be transported by the combination of road-haul and low-ground-pressure vehicles over the routes indicated in the sectional contingency plan for the prevailing environmental conditions. The pre-tested replacement pipe sections and the heavy equipment required for excavation and pipe handling will be moved to the repair site by appropriate surface transport means.

Line Repair Procedures

(a) The repair sequence will begin with steps to create a safe environment for the repair activity including: complete depressurizing of the line section through the blowdowns at the mainline block valves at each end of the section, the introduction of a flow of air into the line at the rupture by means of aspirators installed on the blowdowns subsequent to depressurization, and the monitoring of the break site until a gas-free condition is achieved.

(b) When the repair site has been made safe, the continuing repair operations will include:

- installing terrain protective mats in the vicinity of the break;
- diverting any water flowing across the right-of-way in the repair site areas by means of conduits or other temporary structures;
- removing of any water which may have entered the line;
- excavating to completely expose the entire section of damaged pipe and appropriate adjoining lengths of sound pipe;
- cutting and removing the damaged pipe from the excavation;
- preparing the remaining pipe ends for welding;
- joining the pre-tested pipe sections by welding if more than one pipe length is required;
- lowering the replacement pipe into the excavation;
- tying in the replacement pipe by welding to the prepared remaining ends of the pipeline;
- commencing the purging of air from the repaired section with natural gas;
- making radiographic inspection of the welds made in the repair;
- completing the purge;

- equalizing line pressure on the damaged section with that of adjoining sections;
- opening the mainline block valves and re-activating their operators;
- completing the external coating over the length of the repaired section;
- backfilling the excavation and restoring the right-of-way;
- restoring the vegetation in a manner similar to the one used during construction (backfilling and restoration may be temporary, pending a season suitable for permanent repairs);
- resuming control of the repaired section of line by the Gas Control Centre on completion of the repair and on advice from the District Superintendent; and
- demobilizing and returning to their usual locations all manpower and equipment involved in the repair activity and removing all waste materials from the site to the approved locations for disposal.

Reporting:

When the line repair is completed and the pipeline is returned to normal operation, the District Superintendent will prepare a comprehensive report for submission to the Applicant's management and relevant government agencies. This report will describe the full sequence and timing of events from detection of the leak through completion of the repair, assess any resulting operational and environmental damages, and endeavour to determine the cause of the incident so that corrective measures can be made to avoid its reoccurrence.

6.2 Unscheduled Major Station Repairs

The lockout alarms and station emergency alarms will alert any on-site personnel, the Gas Control Centre and the relevant District Office that a complete compressor station or a major unit thereat is shutdown. As a major unscheduled station shutdown reduces system capacity significantly, the repair must be made as expeditiously and efficiently as possible. In the proper circumstances, the effect of the shutdown can be lessened by increasing the output of onstream stations.

As in the case of a major line repair, there will be contingency plans developed for each compressor station using the principles set out in the previous Section 13.b.6.1. As all the compressor stations will be accessible by aircraft or highways and will have equipment and, at some times, manpower on site, equipment and manpower logistics will be simpler than they would in the case of a major line repair to a portion of the line which is remote from a compressor station.

As described in detail in Section 13.b.3.3, Warehousing and Storage, the Applicant will ensure that all critical spare parts are readily available so that turbine or compressor repairs will not be delayed. The Applicant will also develop a modular spare parts system so the faulty part can be quickly replaced and returned to the Applicant or manufacturer's service centres for servicing and analysis.

6.3 Fires

6.3.1 Procedures

The Applicant will comply with gas industry standards which have been developed to promote safe working practices and to establish emergency procedures in fire situations. These procedures include fire safety training, the use of non-sparking tools, the designation of restricted smoking areas, the granting of hot work permits for hazardous jobs, and special procedures governing the operation, maintenance and refueling of heavy work equipment and the replenishment of fuel storage facilities. To the extent that such practices and procedures must be amended to reflect the particular design and operating aspects of the pipeline, the Applicant will, upon consultation with the relevant government officials and with its advisors, develop practices and procedures to ensure that its fire prevention and fire-fighting capabilities are in excess of the minimum requirements.

The presence of the Applicant in sparsely populated areas and its extensive communications system will assist in the early detection of forest and tundra fires and the mobilization of fire-fighting forces and equipment. Equipment to be used to fight fires along the pipeline will be stored in suitable containers for ground transport or airlift by helicopter. Radio-equipped ground transportation equipment and heavy work equipment will be stored at locations along the pipeline. Transportation of personnel and equipment to the site of a fire will be by the mode which, in the judgment of District supervisory personnel, will be appropriate to meet the type and location of the fire to be fought. Contingency plans for fire fighting will be developed in the same manner as described under Section 13.b.6.1, Major Line Repair.

The following paragraphs describe the general principles which the Applicant will utilize in establishing its fire procedures for the different aspects of its operations.

Compressor Stations

Each compressor station will be "fail safe" with respect to fire and gas detection and fire extinguishment. A fire detection system will sense a fire in any of the main compressor station buildings by means of photo-electric, fire-sensing eyes and heat rise detectors, and the emergency shutdown system (see Section 8.b.1.4.3, Compressor and gas Measurement Stations), will be activated which will shut the station units down and isolate the station from the rest of the pipeline. At the same time, an inert clean agent gas will be automatically discharged into the building where the fire is located, displacing the oxygen content and smothering the fire.

When the emergency shutdown system is activated at the compressor station, a fire alarm will be displayed on the Gas Control Centre and District Headquarters alarm panels and will sound at the station. District personnel will be alerted and dispatched to the compressor station site to assess the situation and report by radio to the District Supervisor. Should the fire be of a major nature, the relevant local government authorities will be advised. Any small residual fire will be extinguished by use of onsite, wheeled and hand-operated fire extinguishers. The likelihood of fires spreading from the large gravel pads on which the compressor stations will be constructed to the surrounding forest or tundra will be small and further reduced by having an unforested area around each compressor station gravel pad.

When a compressor station fire is extinguished, an assessment of the damage will be made and the cause of the fire isolated and corrected. All fire-extinguishing equipment will be recharged and returned to service. The Auxillary Support Systems will be restored to provide lighting, ventilation and building heat. Station operating equipment repairs will follow the relevant contingency plans for unscheduled station repairs described in Section 13.b.6.2, Unscheduled Major Station Repairs.

Fire Crossing or Initiating on the Right-of-Way

While on the right-of-way, maintenance crews will be provided with portable fire-extinguishing equipment. Because of their training and awareness of the problems of fire, it is extremely unlikely that fire will even initiate, much less get out of control, around their work areas on the right-of-way.

The Applicant recognizes that fire caused by non-pipeline sources could cross the right-of-way before preventive measures can be taken. There is no immediate danger to the operation of the line from such a fire. There is a possibility of soil instability developing in some areas because of the damage to the vegetation cover caused by such a fire. This damage would be corrected by the maintenance personnel as soon as practicable after the fire has passed. Steps in rehabilitating ground disturbances are discussed in Section 13.b.6.3.2, Environmental Considerations After Fires.

The mobilization of men and equipment for right-of-way fires will parallel that for compressor station fires. When a fire which endangers the right-of-way is confirmed, the local fire officials will be notified and advised of the situation, and liaison will be maintained with such officials for the duration of the danger. If the pipeline's operating conditions permit, personnel and equipment will be immediately dispatched to the site and will be prepared to act under the control and direction of the relevant fire officials.

Forest or Tundra Fires

During the course of maintenance trips and line patrols along the pipeline, the operations and maintenance staff will be on the lookout for grass, forest or tundra fires. When a fire is spotted, the relevant local governmental fire officials will be notified. Requested manpower and equipment which is not basic to the continuous, safe operation of the pipeline will be made available to assist with the control of such fires. The fire officials will be kept fully informed of the Applicant's equipment and manpower capabilities along the pipeline.

Town or Community Fires

In towns or communities where the Applicant's operations are developed, fire prevention and fire fighting facilities and procedures will be co-ordinated with local fire prevention authorities.

6.3.2 Environmental Considerations

The Applicant will use conventional means of restoring the right-of-way cover in the non-sensitive terrain regions. In sensitive terrain regions, the environmental impact caused by a fire will vary with the intensity of the burn, with a light fire likely only to consume only the uppermost layer whereas a severe fire could destroy all the vegetation and humus cover.

In the latter case, the burned area, unless promptly repaired, may be subjected to wind and water erosion and, in regions of permafrost, the possible degradation of permafrost resulting in surface recession. All areas so damaged which are significant to the integrity of the line will be promptly restored. The restoration could follow several methods depending on the size of the area and the time of year. A temporary repair could involve the covering of the damaged area with insulated pre-formed blankets or a mat of straw which would be held in place by nylon or wire netting. If insulation is not a requirement, the area could be covered with nylon or wire netting only. This procedure will temporarily greatly reduce the wind and water erosion tendency. The final permanent repair will involve revegetating the area in a manner similar to that used in the construction phase (see Section 13.a.6.7, Clean-up and Restoration).

4.1.2.4 Stipulations for Right-of-Way Grants, Permits, Leases and Contract Sales Required by the Federal Government

Stipulations that could be conditions for grants-of-lands and other permits required by the Applicant form another avenue through which adverse environmental impacts could be mitigated, provided that the stipulations were adequate and correct in their requirements and rigidly adhered to and enforced.

The Government of Canada has not formulated stipulations that would apply to the proposed pipeline. It has, however, devised and published guidelines with the intent of "...making known its current views on ...construction and operation of oil and gas pipelines in the Yukon Territory and the Northwest Territories". Since the intent of the Government is to "...translate...these guidelines into action, where this is appropriate...", the guidelines provide some measure of the stipulations that might have to be met if the proposed project were implemented. Accordingly, the guidelines are quoted in their entirety in this section of the Statement.

Two provisions of the guidelines merit special emphasis: 1) the government would require that the Applicant post a performance bond in support of conformance with environmental regulations, and 2) the Applicant would pay for the monitoring service set up by the government.

The guidelines were formulated for development of pipelines north of 60° N. latitude. What guidelines, stipulations and regulations would apply to environmental concerns south of 60° N latitude is unknown.

EXPANDED GUIDELINES
FOR
NORTHERN PIPELINES

as tabled in the house of commons June 28, 1972
by the honorable Jean Chretien

Available on request
from the Department of Indian Affairs
and Northern Development

No. 72 - 3

FOREWORD

The Government is today making known its current views on expanded guidelines for the construction and operation of oil and gas pipelines in the Yukon Territory and the Northwest Territories. The proposed guidelines deal with the corridor concept, the environment, and social implications, and are a further elaboration of those announced in August 1970 by the Minister of Energy, Mines and Resources and the Minister of Indian Affairs and Northern Development.

The Government's purpose in expressing these latest views is to give further guidance to industries engaged in research and planning in connection with northern pipelines and to afford the opportunity to northern residents, and all others concerned to make observations on the guidelines proposed.

In particular, the Government is ready to sit down with the representatives of the native peoples involved, invite their views on the guidelines proposed, and reflect these views wherever possible.

It is the Government's intention, after making any such modifications, to bring these expanded guidelines into force on or about December 31, 1972.

Preamble

Initial Canadian government guidelines for construction and operation of northern pipelines, were announced by the Ministers of the Departments of Energy, Mines and Resources and Indian Affairs and Northern Development in August 1970. At that time, it was stated that further guidelines might be issued. As a result of further studies, research and investigations that have been carried out since 1970, it appears timely to issue expanded guidelines as quickly as possible. Proposed new guidelines on the corridor concept, the environment, and social implications (items 2, 6 and 7 of the August 1970 guidelines) are set out hereunder. These guidelines are Government's current views on what should be included in the northern pipeline guidelines. The Government's purpose in expressing these latest views is to give further guidance to those engaged in research and planning in connection with northern pipelines and to afford the opportunity to northern residents and all others directly concerned to make observations on the proposed guidelines. In particular, the Government is ready to sit down with representatives of the native peoples involved, invite their views on the guidelines proposed, and reflect these views wherever possible. It is the Government's intention, after taking into consideration any observations that may be made, to bring these expanded guidelines into force on or about December 31, 1972. It should be emphasized that the guidelines may be further revised after that date should further pertinent and significant information become available.

Items 2, 6 and 7 of the August 1970 guidelines read as follows

"2. Initially, only one trunk oil pipeline and one trunk gas pipeline will be permitted to be constructed in the North within a "corridor" to be located and reserved following consultation with industry and other interested groups.

"6. The National Energy Board will ensure that any applicant for a Certificate of Public Convenience and Necessity must document the research conducted and submit a comprehensive report assessing the expected effects of the project upon the environment. Any Certificate issued will be strictly conditioned in respect of preservation of the ecology and environment, prevention of pollution, prevention of thermal and other erosion, freedom of navigation, and the protection of the rights of northern residents, according to standards issued by the Governor General in Council on the advice of the Department of Indian Affairs and Northern Development.

"7. Any applicant must undertake to provide specific programs leading to the employment of residents of the North both during the construction phase and for the operation of the pipeline.

For this purpose, the pipeline company will provide for the necessary training of local residents in coordination with various government programs, including on-the-job training projects. The provision of adequate housing and counselling services will also be a requirement."

General

Public comments on the guidelines that follow are invited. Specific comments and suggestions are invited from both the general public and industry with respect to the concept and design of a transportation corridor that might include in the long run not only trunk pipelines, but also a highway, a railroad, electric power transmission lines, telecommunication facilities, etc. Comments and suggestions should be addressed to:

> Director, Environmental-Social Program, Northern
> Pipelines, Room 365D, Centennial Tower, 400 Laurier
> Avenue West, Ottawa, Ontario. K1A 0H4.

These guidelines refer only to trunk pipeline systems over land and associated bodies of fresh water on the mainland north of 60° and do not apply to pipelines that may be proposed for the Arctic Islands and intervening marine areas.

These guidelines apply to all aspects of oil or gas pipeline pre-construction, construction, operation and abandonment, including not only the actual right-of-way, but also all associated and ancillary facilities such as roads, docks and landing areas, storage areas, airstrips, pumping or compressor stations and communication and maintenance structures.

The term "Applicant" refers to the pipeline applicant, its agents, contractors and subcontractors.

The term "Native People" refers to Indian, Eskimo and Metis people in the Yukon Territory and the Northwest Territories.

In order to translate the intent of these guidelines into action, where this is appropriate, the Applicant will be required to enter into agreements containing covenants that detail specific undertakings. Two general undertakings in each agreement or contract will be: that the Applicant shall be required to post a performance bond respecting the execution of the contractual undertakings, and the security deposit for the bond will be in the form of (a) a promissory note guaranteed by a chartered bank, payable to the Receiver General, or (b) a certified cheque drawn on a chartered bank payable to the Receiver General, or (c) bearer bonds issued or guaranteed by the Government of Canada, or (d) a combination of the securities mentioned in (a), (b) and (c); and that the Applicant shall cooperate with the monitoring service set up by the government to ensure contract compliance, and the cost of the monitoring service will be a charge to the operation.

These guidelines are not to be construed as substitutes for the requirements of applicable acts, ordinances or regulations.

Pipelines "Corridor" Guidelines

Introduction

The 1970 Guidelines made provision for the establishment of a "Corridor" to enclose trunk oil and gas pipelines. The following comments and proposals relate to the application and implementation of this corridor concept.

Purpose and Use of "Corridor" Concept

Control of pipeline routes is required to minimize environmental and social disturbance, to ensure maximum benefits to northern residents and communities, and to channel resource development in accordance with governmental priorities. In approaching the concept of a pipeline "corridor", the Government of Canada recognizes the need for flexibility in the choice of pipeline routing in consideration of resource and market locations, economics, engineering and construction requirements, and the severity and sensitivity of Arctic terrain conditions.

The concept of "one trunk oil pipeline and one trunk gas pipeline" within a "corridor" was enunciated with the intention of confining environmental and social disturbance resulting from trunk pipelines to a narrow zone, thus limiting insofar as possible the geographic area involved in these disturbances and leaving as much as possible of our northern lands in an undisturbed state. On the other hand, it is recognized that restriction of both oil and gas pipeline construction activities to a narrow "corridor" would lead to increased intensity of land use and the possibility of unacceptable environmental and social disruption. The routing of oil and gas pipelines close to other transportation-communication systems (and the probability of subsequent development of such systems adjacent to pipelines) may add to problems of maintaining the environment. Even minor disturbances arising from adjacent developmental activities may reinforce one another to produce cumulative ecological disruptions. Moreover, local shortages of gravel or other granular materials may result from close spacing of construction projects. In addition, the differing terrain requirements of oil and gas pipelines may prevent adjacent routings under some circumstances. Thus, caution will be required in defining specific routes or "corridor" boundaries.

"Corridor" for Trunk Pipelines in Yukon Territory and Mackenzie Valley Region

Information is presented here concerning the general routing of pipeline "corridors" and applications for pipeline permits across the northern portion of the Yukon Territory and through the Mackenzie Valley region of the Northwest Territories, to carry oil and gas to southern markets from sources in this part of Canada and/or from the Alaska north slope. The present comments apply only to trunk pipelines in the area outlined above, and do not apply to pipelines or "corridors" that may be proposed for other parts of the Yukon Territory and the Northwest Territories.

1. The Government of Canada is prepared to receive and review applications* to construct one trunk oil pipeline and/or one trunk gas pipeline within the following broad "corridors";

   i) Along the Mackenzie Valley region (in a broad sense) from the Arctic coast to the provincial boundary;

   ii) Across the northern part of the Yukon Territory either adjacent to the Arctic coast or through the northern interior region from the boundary of Alaska to the general vicinity of Fort MacPherson, and thus to join the Mackenzie "corridor";

2. To confine the environmental (and social) disturbance arising from pipelines and their construction to a limited area, trunk oil and gas pipelines within the corridors outlined in 1. above are to follow routes that are as close together as is consistent with the differing engineering constraints and environmental hazards of the two types of pipelines, but not so close together as to bring about undesirable environmental interaction between the two lines. The same principle is also to apply where the trunk pipeline route lies parallel and near to a present or proposed highway or other overland communication system.

3. In view of the influence of the first trunk pipeline in shaping the transportation corridor system and in molding the environmental and social future of the region, any applicant to build a first trunk pipeline within any segment of the corridor system outlined in 1. above must provide with his application:

   i) assessment of the suitability of the applicant's route for nearby routing of the other pipeline, in terms of the environmental-social and terrain-engineering consequences of the other pipeline and the combined effect of the two pipelines; (fully engineered proposals concerning the other pipeline are not necessarily required);

   ii) assessment of the environmental-social impact of both pipelines on nearby settlements or nearby existing or proposed transportation systems; and

   iii) comparison of the applicant's proposed route with alternative pipeline routes, in terms of environmental and social factors as well as technical and cost considerations; (fully engineered proposals concerning alternative routes are not necessarily required).

4. In relation to the pipeline corridors identified in 1. above, the Government will identify geographic areas of specific environmental and social concern or sensitivity, areas in which it will impose specific restrictions

---

* Applications are to be filed with the National Energy Board for a Certificate of Public Convenience and Necessity, and with the Department of Indian Affairs and Northern Development, under the Territorial Lands Act, for tenure of land comprising the pipeline right-of-way.

concerning route or pipeline activities, and possibly areas excluded from pipeline construction. These concerns and restrictions will pertain to fishing, hunting, and trapping areas, potential recreation areas, ecologically sensitive areas, hazardous terrain conditions, construction material sources, and other similar matters. Statements announcing the above will be released through the office of the Director, Environmental-Social Program, Northern Pipelines.

5. If and when an applicant has received governmental authorizations to construct and operate any trunk pipeline, it is contemplated that Land Management Zones under the Territorial Lands Act and/or Development Areas under the Area Development Ordinances would be established to encompass the pipeline route and the additional lands required for ancillary facilities such as roads, staging areas, gravel and borrow pits, construction camps, etc.

Environmental Guidelines

Introduction

Guideline No. 6 of August 1970 required that any applicant "must document the research conducted and submit a comprehensive report assessing the expected effects of the project upon the environment". The amplification of this guideline presented below registers some current environmental concerns of government and is intended to indicate to potential applicants some of the major topics that should be included in such an environmental assessment. These concerns are registered in general terms but applicants are to respond in some detail in their environmental assessment with specific engineering design data and proposals that take into consideration the conditions encountered along their particular route. In responding to these concerns, applicants also are to provide documented evidence that they possess not only the necessary knowledge, but also the capability to carry out the specific proposals. As indicated in the 1970 guidelines, applicants will have available, and may be required to submit, all background data upon which the environmental assessment is based. However, the focus should be on specific responses to the concerns outlined below. In connection with these environmental concerns, government may impose restrictions or exclusions on pipeline activities in specific geographic areas that are environmentally sensitive, as outlined in Section 4 of the Pipeline "Corridor" Guidelines.

Guidelines: Some Current Environmental Concerns of Government

Any applicant for a Certificate of Public Convenience and Necessity and for right-of-way and other related land requirements, must submit a comprehensive assessment, based upon documented research, of the expected effects of the project upon the environment. Any certificate issued will be strictly conditioned with respect to applicable statutes providing for the protection of the environment and the following environmental concerns of government:

1. that a pipeline be constructed*, operated and abandoned in keeping with good engineering practice to ensure its safety and integrity, in the interests of good environmental management and the reduction of environmental damage;
2. that construction, operation and abandonment of a pipeline will be done so as to avoid or minimize adverse effects upon the surrounding terrain, including vegetation, and aesthetic damage to the landscape;
3. that rivers and other waterbodies will be approached and crossed, either overhead or underground, in a way that will minimize environmental disturbance to the waterbody itself, to its bed and banks, and to the adjacent land or vegetation during construction, operation, and abandonment of a pipeline;
4. that a pipeline will be constructed, operated and abandoned with a minimal disruption to river and lake regimes, water quality, and feeding, reproduction and migrating stages of fish and other aquatic organisms;
5. that a pipeline will be constructed, operated and abandoned with minimal interference to the lands and vegetation that serve as feeding, reproduction and migrating areas for mammals and wildfowl, and with maximum protection to rare or endangered species and their habitats;
6. that adequate provision be made for disposal of sewage, garbage and various gaseous, liquid and solid wastes and all toxic materials during construction, operation or abandonment phases of the project;
7. that adequate provision be made for preservation or salvage-excavation of archaeological and historical sites, and that minimal damage to such sites will result from pipeline activities;
8. that effective plans be developed to deal with oil leaks, oil spills, pipeline rupture, fire and other hazards to terrestrial, lake and marine habitats, that such plans be designed to minimize environmental disturbances caused by containment, clean-up or other operations and to bring about adequate restoration of the environment, that they be designed to deal with minor and major incidents, whether they are single-event or occur over a period of time and that they include contingency plans to cope with major hazards or critical situations;
9. that an effective plan be developed for implementation of specific environmental safeguards through an educational program for field personnel prior to and during construction and operation of the pipeline;
10. that an effective pipeline performance monitoring system of inspection and instrumentation be established to ensure

---

* Where the words 'construction' or 'constructed' are used they are meant to include preconstruction activities of a pipeline project.

operational performance in keeping with the above-stated environmental concerns.

Suggested Topics for Response to Environmental Concerns

Examples of the kinds of topics that could be included in an applicant's environmental assessment in response to these environmental concerns of government are presented below. The items are numbered to coincide with the arrangement of the ten environmental concerns in the foregoing section. The listing of topics is not complete and the material is not intended for use as a formal checklist.

It is suggested that specific proposals or information be presented regarding the following:

1. Safety and integrity of the pipeline (items applicable to this concern are incorporated in concerns 2 - 10 immediately below).

2. Terrain and vegetation

   a) methods of handling potential problems in relation to earthquakes, landslides, avalanches, or terrain changes resulting from thawing of frozen ground;

   b) methods of minimizing removal of vegetation and the organic mat in permafrost areas with high ice content;

   c) methods of minimizing interference with the movement or quality of water on and in the ground with particular attention given to the expected boundary or limit of influence: where drainage disruptions are expected, the boundary of influence may be well beyond the actual area of construction;

   d) methods of minimizing the loss of strength and volume of soil as a result of melting of ground ice, particularly if the ice occurs in segregated masses; if such melting cannot be entirely prevented then there should be indications of how consequent instability and differential thaw-settlement is to be minimized;

   e) safeguards to be taken against potential dangers to a pipeline from differential vertical movement caused by uneven settlement from thawing of permafrost materials or from "growth" of permafrost; where soil collapse over ice masses and differential flotation and sinking over liquified soil could deform or rupture pipe, proposed safeguards should be identified;

   f) methods of maintaining slope stability in general

   g) methods of construction and location of permanent facilities in a way that will harmonize with their natural setting;

   h) removal and/or appropriate disposal, of debris created by construction activities and plans for buffer strips of natural vegetation between public roads and pipeline facilities;

i) quantity and quality of aggregate or borrow materials required, details of the geographical distribution of the requirements and proposals as to sources of the required material, including proposed access routes from pit or quarry to point of use, and restoration of pits and quarries;

j) plans to carry out assisted revegetation or alternative methods of providing and insulating cover on which natural revegetation can occur;

3. River and lake crossings

a) for river or stream crossings installed beneath the watercourse, depth of maximum anticipated scour and depth of proposed placement of pipe, supported by bore-hole logs and other data indicating the scour depth;

b) design of approaches to river crossings so as to maintain stability of walls and river banks and to minimize changes that could lead to slope failures; gullying and related disturbances;

c) design of underground crossings of rivers and streams that could withstand the effects of run-off, bank erosion, meander cutoffs, lateral migration of stream channels, ice jams, and icings, the magnitudes of which should be calculated according to reasonably expected extremes for a particular stream crossing area;

d) design of approaches to and crossings of ponds or lakes, with particular reference to degradation or growth of ground ice, and shore or bank regression or collapse through thermokarst or other processes;

4. River and lake regimes

a) methods for construction of stream and river crossings in a way that will minimize interference with fish passage or degradation of aquatic habitats through erosion and sedimentation;

b) alternative fish passage structures in cases where the proposed project requires stream channel modification that would obstruct migrating fish;

c) schedules of construction activities and evidence that the project contains the flexibility to allow pipeline, road, or other construction to cease for periods of time when important areas critical to fish, wildlife, or waterfowl are temporarily threatened;

d) methods of minimizing the addition of sediment and introduction of oils and greases into water bodies as a result of preconstruction or construction activities, particularly in respect to access roads and ice-bridges;

e) proposed location, volume, composition and disposal of pipeline test fluids;

f) plans to restore fish and wildlife habitats that are damaged by pipeline activities;

g) dates and proposed methods of construction within 300 feet of any water body frequented by fish;

5. Wildlife

a) methods of minimizing the restriction of movement of wild animals such as caribou;

b) methods of protection of wetland areas used as feeding, breeding, or staging areas by migratory waterfowl or as habitat for fur-bearers;

c) methods of minimizing harassment and other impact upon wildlife populations from greatly increased human intrusions and the operation of boats, ground vehicles, aircraft, and compressor or pumping stations;

d) safeguards proposed and alternatives that were considered for the habitats of rare or endangered species;

e) control of possession of firearms in construction camps and on construction operations;

6. Waste and toxic material

a) methods of waste disposal to avoid health hazard to humans and animals as well as aesthetic pollution; information should be provided on use of water from streams, springs or lakes for domestic, camp or construction purposes and on location of camps and sewage disposal systems relative to local drainage patterns;

b) how ice fog accumulation and air pollution will be minimized;

c) the nature, transportation and use of any pesticides, herbicides, pipe coating materials, anti-corrosion materials, flushing agents, or other toxic substances, proposed for the project, and information on their expected persistence and mobility in surrounding ecological systems;

7. Archaeological sites

a) archaeological surveys to identify prehistoric sites prior to and during construction phases of a pipeline project;

b) procedures to promote recognition, reporting, and assessment of archaeological materials encountered in pipeline activities, including orientation of construction personnel;

c) arrangements for preservation or salvage-excavation of sites judged to be of archaeological significance;

8. Contingency plans

a) how the possible loss of oil or gas through pipeline leaks would be routinely detected and stopped quickly (the maximum potential undetected loss from the pipeline should be specified and evidence provided. This value is to be as low as is technologically feasible);

b) how oil which has escaped into the terrestrial, lake or marine environment would be detected, how it would be disposed of and how the elements of the environment affected by the oil would be rehabilitated;

c) methods to prevent burning of vegetation and proposals for a general contingency plan for fire prevention and suppression on the right-of-way, on the immediately surrounding land, and on lands involved in ancillary activities during preconstruction, construction, operation, and abandonment phases of the project;

9. Environmental briefings

how the applicant intends to carry out environmental briefings to ensure that personnel are fully aware of all environmental restrictions for each construction section and each construction and operational phase of the project, and the reasons for such restrictions;

10. Monitoring

a) continuous surveillance and maintenance programs along the pipeline right-of-way;

b) plans to monitor the environmental side effects during and after construction, including downstream sampling of sediment and potentially toxic materials.

Social Guidelines

Introduction

Guideline No. 6 of August 1970 reads in part as follows: "Any certificate issued will be strictly conditioned in respect of ... the protection of the rights of northern residents, ...". Government recognizes the concerns of the Indian people of the Territories with regard to the construction and operation of northern pipelines. Government is prepared to discuss with the Indian people their land claims and Treaty rights whenever they express their willingness to meet on the matter, and any decisions made concerning northern pipelines will be without prejudice to Indian land claims and Treaty rights. Guideline No. 7 of August 1970 requires the applicant to undertake specific training programs, to employ residents of the North during the construction and operational phases of the pipeline, and to provide adequate housing and counselling service. The following social guidelines are an elaboration of those issued in 1970. They are consistent with Canada's policy on northern development. They give priority to a higher standard of living and equality of opportunity for northerners by means compatible with their own preferences and aspirations. In addition, they seek to minimize the adverse social and economic consequences associated with rapid large-scale development, where these adverse affects can be predicted with some degree of certainty.

Guidelines:

1. The Applicant must undertake specific programs leading to the employment, at all occupational levels, of residents of the territories - and in particular native people, during the construction and operation of the pipeline. Such programs or projects shall include but not be limited to: advance information on all jobs in a manner that ensures that the information reaches potential workers; skills required for various occupations and anticipated duration of employment; upgrading and skill training; other forms of integrated training that include on-the-job work experience; and counselling for those unfamiliar with industrial jobs or wage style living. All training, orientation and counselling courses will be planned and carried out in co-operation with the various agencies of government responsible for these matters. The pipeline companies shall have particular responsibility for on-the-job work experience.

2. Priority placement in jobs shall be accorded native people of the territories in keeping with the tenor of Article 5 of the International Labour Organization Convention 111, 1958, ratified by Canada, and the government's intent to increase employment opportunities for members of disadvantaged minority groups. During the consultation between government, unions and employers as outlined in the Convention, ways and means will be found to ensure access for these employees into the appropriate union locals and hiring halls where there is a requirement. In addition, in accordance with the principle of employment of local workers which is accepted by organized labour, the Applicant will employ labour from the locality where work is being executed to the extent it is available. The Applicant shall comply with the above Convention and employment principles, and cooperate with government's effort to operate an effective recruitment, placement and counselling service.

3. The collective agreements signed by the Applicant and organized labour shall not distinguish between residents of the territories and others respecting special benefits and allowances, including housing for operational staff, and the nature of these benefits shall be in no way inferior for employees from the territories. In addition, in situations where special measures are required to ensure the employment of native people as outlined in the International Labour Convention 111, the Applicant shall negotiate special agreements related to the employment of native people, in consultation with the native people and government. Related to the above matters but not restricted thereto is the requirement for the Applicant to set up special orientation and consultation machinery to familiarize its staff and employees with the culture and aspirations of native people and of territorial residents generally. Conversely, this orientation and consultation will acquaint employees from the territories with the pipeline industry and the work habits and life style of non-territorial employees. The

orientation and consultation activity shall be planned and operated with the participation of native people, other northern residents, organized labour, the Applicant and the appropriate governmental agency that will coordinate and monitor the various functions performed.

4. Contracts and sub-contracts shall be so designed and publicized as to invite and encourage bids from native organizations, settlement councils and local contractors. In addition, the businesses and commerical organizations of the territories shall be invited and encouraged to supply goods and services required for the pipeline development and operation.

5. A substantial number of native people depend on trapping and hunting as a principal means of livelihood, and many derive a real satsifaction from being on the land and being master of a familiar environment. Therefore, the pipeline will be constructed, operated and abandoned with minimal interference to traditional trapping, hunting and fishing areas. In addition, where the pipeline construction is planned to be located in proximity to a settlement--particularly a native settlement or localized area subject to intensive use, then the location of construction camps, associated activities and the detailed siting of the pipeline will be decided by government after consultation with the Applicant, and the settlement council, or local government body, or the native organization.

6. Where the construction, operation or abandonment of a pipeline results in loss or damage to the undertakings or property of territorial residents - and native people in particular - then the Applicant shall deal promptly and equitably with all reasonable claims.

7. In order to ensure that the social and economic benefits outweigh the costs, the Applicant shall make a conscious effort to contribute to the social and economic development of the territories. This objective shall have particular relevance regarding locating permanent infrastructure and maintenance facilities so that their presence will be to the benefit of communities; preserving scarce resources such as aggregate and forest products required by communities - both present and future demands; assuring residents reasonable access to transportation and communication facilities associated with the pipeline system; making gas energy available to selected territorial communities at places and costs to be negotiated between the Applicant and the appropriate governmental agency; and the Applicant shall give prior consideration to the territorial governments - concerning the disposal of all surplus facilities, equipment, or infrastructure, at a place to be negotiated between the Applicant and the respective government.

8. The pipeline construction activity shall be selfsufficient with respect to certain service such as sewer and water, power, roads, fire prevention, recreation services and emergency health services unless there is a prior agreement to the contrary. With respect to other public services that by their nature must remain under public control such as police protection, base hospitals and like services, there

will be early consultation with the appropriate level of government to ensure adequate preparation and continuing liaison during the construction and operation phases to ensure maximum coordination and cooperation.

4.1.2.5 Research and Monitoring

In its Environmental Statement for Canada south of 60° N. latitude the Applicant notes that a portion of its extensive research program would continue into the construction and operation phase of the project. The topics on which research would continue (CAGPL, 1974, 14.d N.6.2, P.7) would be:

"1) continued monitoring of barren ground caribou, other mammals and fish,

2) continued reading of the established bird sites,

3) further disturbance studies of birds,

4) monitoring of Arctic test facilities,

5) a program to increase the supply of native grasses and to ensure an adequate supply of agronomic species and to monitor sites where revegetation has been accomplished,

6) an intensive program of monitoring birds, fish, mammals and vegetation at Chick Lake, together with surface and subsurface drainage studies and

7) studies on slope stability, stabilization measures, drainage and erosion control measures and frost effects."

A research program has no direct mitigating effect, however, unless its recommendations for lessening impact are implemented.

Monitoring the construction and operation phases of the proposed pipeline system could lead to mitigation of adverse environmental impacts provided action is taken when premonitory signals are received. The Applicant's monitoring plans, which have been described in some detail under maintenance (1.1.2.7, this Statement), include provisions for monitoring both the pipeline and attendant facilities and the environment in which it would be built. Monitoring the pipeline system for leakage or other malfunction would involve: 1) Continuous scrutiny of gas transmission by the computer system located at the Calgary Gas Control Center. Throughput data would be obtained automatically at compressor and measuring stations and relayed to Calgary through the microwave communication system. The monitoring system would detect gas escape, among other things, and could specify the 40-mile segment in which leakage was occurring. 2) Scheduled maintenance and inspection visits to compressor stations and other facility sites by operating and maintenance personnel would provide opportunities for detecting equipment malfunctions. 3) Aerial surveillance of the right-of-way and other facilities at intervals of from one to several weeks, weather permitting, would monitor areas of erosion or mass wasting that might expose or damage the pipe.

The Applicant's environmental monitoring program for the construction and operating phases centers around employees designated as Environmental

Inspectors (CAGPL, 1974, 14.d N.6.2, p. 4). During construction, Environmental Inspectors would be located on each working spread and would have authority to require compliance with construction rules and design provisions (4.1.2.1, this Statement) intended to safeguard the environment. During operation, inspectors would engage in aerial and ground surveillance of terrain conditions, revegetation progress and wildlife populations that either were or would be disturbed by operation and maintenance activities.

Plans for monitoring the proposed pipeline system by the Government of Canada are less clear, although the "Expanded Guidelines for Northern Pipelines" (Department of Indian Affairs and Northern Development, 1972, p. 5) envision a government monitoring system paid for by the Applicant. What would be monitored, how frequently it would be done and what methods would be used are not specified. The Environment Protection Board, an independent panel sponsored by Canadian Arctic Gas Study Limited, has recommended establishment of an Environmental Auditor Group to monitor construction and operation of the proposed pipeline system in the public's behalf (Environment Protection Board, 1974, v. 1, p. 75). The status of these proposals by the Government and the Environment Protection Board for monitoring the proposed project are unknown.

4.1.2.6 Liability and Compensation for Losses Incurred during Construction and Operation

What liabilities the Applicant would assume have not been specified. As noted in 4.1.2.4, this Statement, the Government of Canada's "Expanded Guidelines for Northern Pipelines" (Department of Indian Affairs and Northern Development, 1972, p. 4) would require:

> "...that the Applicant...post a performance bond respecting the execution of the contractual undertakings, and the security deposit for the bond will be in the form of (a) a promissory note guaranteed by a chartered bank, payable to the Receiver General, or (b) a certified cheque drawn on a chartered bank payable to the Receiver General, or (c) bearer bonds issued or guaranteed by the Government of Canada, or (d) a combination of the securities mentioned in (a), (b) and (c)..."

The "contractual undertakings" between the Government and the Applicant presumably involve conformance to environmental regulations. The status at law of the performance bond guideline is unknown.

4.1.2.7 Other Measures Which Could Further Reduce Environmental Impacts

Training Programs

A commitment to preferential hiring policies for the resident northern natives could be relatively meaningless if these people were relegated to unskilled and semiskilled positions while workers from southern Canada were awarded the more demanding and lucrative jobs by virtue of the competitive advantage they enjoy. The resulting disparities could lead to racial tensions and other social problems that would have a negative impact.

Accordingly, the Applicant and its participant companies, in cooperation with the government, have implemented the Northerner Training Program and have established firm plans for the expansion of that program. The importance of providing on-the-job training to upgrade the skills of those who initially accept unskilled or semiskilled positions is also recognized.

Certain basic principles have been established for the development of the training programs. The northern residents should be provided every opportunity to participate in the projected industrial development to the extent which they, individually and collectively, choose. Career development, as opposed to job placement, should be emphasized to permit both vertical and horizontal job mobility, and to allow transferability of skills with the petroleum and other industries. The programs must be a cooperative undertaking between industry, Northerners, and government, and the administration and operation should eventually be assumed by appropriate government departments, with continuing industry support as required. The training should be open ended to permit individuals to advance to the highest skill level that they may be capable of achieving or motivated to achieve. Participation of Northerners in the planning and implementation of the training program should be encouraged and actively pursued.

Northern Natives have been receiving technical training in pipeline and related industries since 1971. This program is administered by an industry task force under the coordination of the Applicant. The sponsoring companies made available 73 training positions during 1973 and all were filled. The program was expanded to 105 positions in 1975; not all have been filled.

The participation of Natives in the technical training programs would be hampered by the generally low level of basic education. For example, as of about 1971, 37 percent of the native population 14 years of age and older in the Impact Corridor had never attended school. Thus, opportunities for and participation in basic general education will have to be increased in order to prepare Natives for the training opportunities in the more highly skilled aspects of pipeline construction, operation and maintenance.

In addition to training programs to enable the northern Natives to meet specific job requirements, the Applicant has proposed instructional programs in basic life skills for trainees and families, and programs in the culture, history and life style of the Natives for supervisors and workers who come from southern Canada or elsewhere with no previous knowledge of the North or its people. Some seminars for supervisory personnel have already been conducted to provide insight into the issues and concerns that are important to northern Natives. This program is conceived to be continuous throughout the proposed project.

REFERENCES

Canadian Arctic Gas Pipeline Limited, 1974, Construction plan (section 13.a) and Operations and maintenance plans (section 13.b): and exhibit in support of applications to the Department of Indian Affairs and Northern Development of the Government of Canada for an authorization to use land and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, chapters individually paginated.

Canadian Arctic Gas Pipeline Limited, 1974, Environmental statement, Canada north of the 60th parallel (section 14.d N): an exhibit in support of applications to the Department of Indian Affairs and Northern Development of the Government of Canada for authorization to use land and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, chapters individually paginated.

Canadian Arctic Gas Pipeline Limite, 1974, Environmental statement, Canada south of the 60th parallel (section 14.d S): an exhibit in support of applications to the Department of Indian Affairs and Northern Development of the Government of Canada for authorization to use land and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, chapters individually paginated.

Department of Indian Affairs and Northern Development, 1972, Expanded guidelines for northern pipelines: No. 72-3 Department of Indian Affairs and Northern Development, 34 p.

Environment Protection Board, 1974, Environmental impact assessment of the portion of the Mackenzie gas pipeline from Alaska to Alberta; Vol. 1 - The Board's opinion: sponsored by Canadian Arctic Gas Study Ltd., 77 p.

5 ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED SHOULD THE PROPOSAL BE IMPLEMENTED

5.1 ARCTIC GAS PIPELINE PROJECT

5.1.2 Canadian Pipeline

5.1.2.1 What is Adversely Affected and to What Degree?

This section summarizes the unavoidable environmental effects which cannot be fully mitigated; these adverse impacts are treated in more detail in section 3.1.2. The effectiveness of the mitigating measures will depend on the final design of the project, the construction and maintenance procedures, the technical and environmental stipulations, and the enforcement and monitoring procedures for carrying out the stipulations. The adequacy of these items will determine the extent and degree of the unavoidable impacts.

Climate

No significant impacts on regional climate would be expected.

Topography, Geology and Soils

The major unavoidable topographic effect would be the formation of at least 108 pits averaging about 14 acres each in area from which borrow material will be excavated. Other topographic effects will include the small mound over the pipeline trench and the foundation pads and excavations, cuts, and fills associated with facilities related to the pipeline. While unavoidable, most of these effects will be minor. In addition, there will be unavoidable topographic changes caused by geologic processes, such as erosion, activated by construction and maintenance activities.

Use of about 30 million cubic yards of irreplaceable construction materials such as sand, gravel and stone would be a major unavoidable impact. Some of these materials might be recovered after conclusion of the proposed project, but a substantial proportion (probably more than half) will be distributed in such a way as to make their recovery infeasible.

In addition, the pits formed by the extraction of such materials could cause surface or subsurface water to be dammed or diverted and thereby cause accelerated erosion, suspended-sediment concentration in streams, and deposition. Access roads and other facilities could also cause some of the same effects; some would be adverse and unavoidable.

Scars in areas of bedrock exposure, such as at quarry sites, and in places where the pipeline trench would be blasted through bedrock, would be virtually unavoidable, although in time the newly exposed rock would weather and the scar would become less obtrusive. In many cases gravel pits would leave unavoidable scars on the landscape; however, proper siting, use, and restoration could minimize this adverse effect.

If mitigating measures are unsuccessful, and it is not certain that the pipeline can be successfully maintained everywhere in permafrost, thawing of ice-rich, fine-grained permafrost materials could locally result in serious impacts such as liquefaction, slope instability, differential settlement of the ground surface, disruption of drainage, and accelerated erosion along as much as 800 miles of the route north of about Milepost 600 on the Main Line and on the Supply Lines.

Adverse effects on agricultural soils will be minor except on the right-of-way of the proposed pipeline, permanent roads, temporary access roads and their graded or filled areas. These effects will be significant only in areas of agricultural development, mostly south of Milepost 1100 on the Main Line and on the Delivery Lines. Disruptions to soil parent materials will be the same as to construction materials. Normal soil-forming processes will restore most soils in the longer term. Adverse effects on agricultural soils could largely be avoided by returning excavated topsoil to the surface.

Water Resources

Excavation of materials and the placement of fill during construction of the proposed pipeline will alter numerous natural drainage channels. Erosion could be accelerated because of the potential for increased velocities and concentrated flows, steepened terrain slopes, soil disturbances and vegetation modification. Changes in the subsurface drainage caused by pipeline construction, soil compaction, or the frozen annulus around a chilled pipe could result in conversion of subsurface flow to surface flow and thus increase erosion. Downslope from the proposed pipeline, decreased subsurface flow could alter the vegetation cover and thus change the hillside stability. Changes in the form of drainage could alter the freeze-thaw, wet-dry, liquefaction, or other characteristics of soils leading to new or accelerated gelifluction, solifluction, soil creep and more rapid forms of mass movement. A principal potential impact of such soil movements will be the disfiguration of the landscape and a decrease in the quality of water.

The proposed pipeline alignment will cross numerous streams and floodplains. Where the pipeline is buried at stream crossings, scour might expose the pipe and cause damage and even rupture. The formation of river icings (aufeis) could affect the integrity of aboveground structures as well as cause unpredictable effects on depths of riverbed scour. The occurrence and development of aufeis is an example of the delicate balance of natural factors; physical disturbance of the system is quickly reflected and often compounded by the development of icings. The presence of a cold pipeline could initiate icings at previously ice-free locations and might upset the stability of channels and hillslopes at unexpected sites.

Drainage diversions due to trenching will be expected. Subsidence will most likely occur because of the thawing of ice-rich permafrost wherever the vegetative ground cover is disrupted. Surface disturbances and subsidence will cause sliding, slumping, and accelerated degradation of permafrost that will have detrimental effects on the terrain as well as endanger the proposed pipeline.

In areas of permafrost much of the proposed pipeline will be constructed using winter or snow roads for access and as a working pad. The surface disturbance, however minimal, could cause thermokarst development, and accelerated erosion, which might result in long-lasting scars on the terrain. In the normal maintenance and operation of the proposed pipeline, the use of winter roads or summer access by overland vehicles will cause additional erosion patterns to develop. The incidence of these activities cannot be estimated and the degree of impact cannot be evaluated. Although improper use of winter snow and ice roads and resultant adverse impacts could be largely avoided, the long-term adverse impacts of vehicles and construction equipment used to meet warm-season pipeline emergencies generally could not be avoided, but are difficult to quantify.

The natural quality of water in streams or lakes will be impaired where construction-related activities, including the removal of vegetation, sand and gravel mining, and grading and filling for roads or camp buildings, add particulate matter. Adverse effects of sedimentation could largely be controlled in the long term but would be unavoidable during construction and could be long enduring.

Nutrient enrichment of small lakes could accelerate eutrophication and deplete under-ice oxygen supply. Sewage disposal to lakes and streams will be avoided and accidental discharge of organic materials will be a minor adverse influence on the nutrient balance of fresh waters.

Contamination of streams and lakes by deliberate or accidental discharge of toxic chemicals will be a short-term, continuing threat to water quality and plant and animal populations both in freshwater and marine environments. The effects could be critical along major waterways but cannot be quantified as they will depend for the most part on the incidence of accidental spillage and leakage of fuel oil and other toxic materials.

Depletion of water, particularly along the Supply Lines, might be critical whether by use for ice roads or by the diversion of surface flows to aufeis. Excessive pumping of water from ice-covered lakes could disturb water supplies needed to support over-wintering fish and other aquatic biota.

Vegetation

Unavoidable effects of the proposed pipeline on vegetation will be relatively insignificant in terms of the total resource of plant communities. Short-term losses of vegetation will be substantial on all land areas occupied by permanent roads, airstrips, compressor stations, wharves, stockpiles, borrow pits and other facilities. On the pipeline right-of-way, clearing of trees will be a long-term loss of forest productivity; destruction of all vegetation along the ditch-line and spoil pile will be a short-term loss subject to correction by revegetation through seeding of grasses and natural invasion by native species; and access lanes and work lanes will be subject to various degrees of vegetation disturbance conditional upon the efficacy of construction and use of snow and ice roads. Assuming the probable success of erosion control measures, there should be no short-term impacts on vegetation on the right-of-way beyond keeping it free of trees. In the long term, following abandonment of the proposed project, all vegetation should recover, although scars would be visible for many decades.

Short-term adverse effects on terrestrial vegetation could result from toxicity of exhaust gases in the vicinity of compressor stations and from drainage disruptions, especially those caused along side-slopes by the refrigerated pipeline in the region of discontinuous permafrost.

Throughout the lifetime of the proposed project, an apparently intractable problem in permafrost zones will be unscheduled maintenance operations requiring movement of heavy machinery over land to meet emergency situations such as pipeline ruptures or fires. Such operations could in the long term cause more damage to vegetation and terrain than will the initial construction of the pipeline. The adverse effects would be especially severe in the Herbaceous Coastal Tundra where soils are ice-rich, recovery of stable terrain and vegetation is slow, and scars on the landscape are highly visible and long enduring.

Aquatic vegetation will be adversely affected by sedimentation, increased turbidity and by toxic chemicals. These impacts could be avoided and it is probable that their short-term effects would be minor. It must be reiterated, however, that the incidence and quantities of accidentally discharged oils and chemicals constitute an unpredictable problem. These materials could have critical but presently unknown effects on the rich plankton populations at the lower surface and within the Beaufort Sea ice pack. These populations are critical to the food web of the Inner Continental Shelf Ecosystems.

Wildlife

Fish

The pipeline along the proposed route should have few unavoidable adverse effects on fish populations if known and planned mitigating measures are successfully employed. Avoidance of over-wintering areas and spawning beds, control of erosion and the attendant siltation of spawning areas, winter construction schedules in the permafrost zone, rigorous control of chemicals and sewage effluents, and design of culverts to avoid water-velocity barriers to fish movements.

A short-term impact will be the cumulative effects of recurring accidental discharge of fuel oil and toxic chemicals into streams. Since the quantities cannot be foretold the significance of potential chemical contamination is difficult to quantify. The hazard must be considered serious, especially along the Mackenzie River, in the Mackenzie Delta, and along the Beaufort Sea coast. In these areas, the presence of wharves, stockpiles, barge traffic, fuel-handling facilities and large numbers of personnel provides maximal opportunity for accidental spills. The downstream concentration of infrequent but large spills or small, slow, frequently occurring leakages could be an extreme hazard to the Mackenzie Delta aquatic ecosystem, including fish.

The proposed pipeline project will be expected to have an effect on sport fishing through use by construction and maintenance personnel and through increased accessibility of the area to the general public utilizing pipeline-related roads and airstrips. It is improbable that pipeline operations will cause short-term adverse effects on subsistence or commercial fishing.

Mammals

Most mammal species should be little affected along the proposed route if planned mitigative measures are employed. Winter construction will avoid contact with the Porcupine caribou herd if stopped in advance of the spring migration and no barriers to movement are left. Control of firearms and prohibition of hunting will remove a principal threat to game animals. Planned right-of-way alignments avoiding denning sites of wolves, foxes and grizzly bears will remove some of the principal threats to these species.

Adverse effects will be expected on such vulnerable species as wolverine, grizzly bear, and polar bear and to tundra populations of wolf. Human presence, disturbance by aircraft, harassment and hunting will adversely affect all of the foregoing as well as calving caribou, moose and Dall sheep. Wolverine will be displaced from its range along the proposed route and grizzly bear will suffer attrition through shooting for reasons of real or imagined threats to safety of personnel. Although most potential adverse effects will be avoidable, noise disturbance by aircraft, harassment, and increased hunting pressure by hunters who benefited by increased accessibility of the area will be short-term threats to game animals and to the subsistence of Native peoples.

Drainage changes could affect important wetland habitat of aquatic furbearers, and accidental spills of fuel oil will have serious effects on these species as well as such sea mammals as seals, walrus, whales, and polar bears.

Birds

Use of the proposed route will adversely affect bird habitats on the right-of-way and areas occupied by permanent facilities but the areas will be small relative to the total habitat resource. Habitat changes off the right-of-way should have no short-term effects on most bird species and will mainly represent fluctuations favoring one population over another in the short term.

Disturbances to migrating, nesting, feeding, molting and staging waterfowl and shorebirds and disruptions to the habitats used for these functions will be potential adverse effects at one time or another over essentially the full length of the proposed route. Especially critical habitat occurs along the Mackenzie River, in its delta, and along the shores, estuaries, lagoons and barrier beaches of the Arctic coast.

Drainage of wetland waterfowl habitat will be a minor effect if these areas were strictly avoided. Wetlands could be deprived of normal water supply, however, due to drainage disruptions which might prove unavoidable.

Disturbances by human presence, aircraft, barge traffic and compressor station noise will be continuing threats to waterfowl, especially along the Arctic coast, and to raptorial birds wherever they occur throughout the length of the proposed route. Winter construction will avoid major threats to birds, but during operations possible adverse effects on birds will depend upon the success of planned controls on aircraft flight-paths and altitudes, firearms, and molestation by personnel. Such controls plus habitat avoidance could relegate most impacts to the avoidable category, but it is highly improbable that the best of procedures will avoid all serious impacts on the high-density breeding-season populations of the northern coastal areas. Aircraft will be the principal short-term threat and must be considered critical although the impact is difficult to accurately predict.

The effects of accidental spills of fuel oils will be a major adverse impact on waterfowl and shorebirds and their habitats. Since the magnitude and incidence of spills is difficult to forecast there is no way of evaluating the effects, but without strict controls there will be a long-term attrition of bird populations from accidental oil discharge to streams and the marine environment. Toxic chemicals will also have a direct adverse effect on birds through mortality or an indirect effect through disruptions of the food web.

Economic Factors

The proposed project will in some degree have an adverse effect on the desire and/or ability of the Natives to follow their traditional hunting-trapping-fishing land-based economy. A trend away from the land-related pursuits toward a wage economy, however, has already been established in many parts of the region of the proposed route. Therefore, in general the proposed project could not be regarded as an initial cause, but it might be a potent factor in augmenting and accelerating this trend.

The relative merits of these contrasting types of economy, and the present and future attitudes and desires of Natives in regard to these pursuits are subject to much conjecture. Apparently there is divided opinion among the Natives, both as individuals and as groups, about which of these economic courses they wish to follow. It is noted, too, that although there may be a stated preference for the land-based pursuits, the practice in recent years has been to abandon them in favor of wage employment, or at least part-time wage employment.

It seems likely that with more exposure to a wage economy, resulting from the proposed project, the Natives, particularly the younger group, will tend to seek and accept wage employment and withdraw from the more arduous and uncertain land-based subsistence lifestyle. In this case the net result might not be regarded as entirely adverse.

Some adverse effect, due to unemployment, might result in the postconstruction phase of the proposed pipeline project when the labor force required will be only a small fraction of that needed during the peak years of construction. Educational programs that will train local residents for the various jobs connected with construction, maintenance and operation of the proposed pipeline potentially might produce more skilled and semi-skilled personnel than could be absorbed by the overall economy in the region after the 2 to 3 peak years of construction activity. The excess people with recently acquired specialized education and skills and perhaps a strong attachment to a wage employment lifestyle will have to move out of their own region to seek similar employment elsewhere, or try to return to a traditional land-subsistence life to which they might no longer be attuned. Some individuals might be content with such a situation and either move away or welcome the opportunity to return to a land-based lifestyle, but others might be totally disrupted by this type of social and economic upheaval.

Other secondary activities in gas and oil exploration and development in the Mackenzie region might materialize and provide continuing employment for those displaced from jobs following the projected peak construction period.

Sociological Factors

To some degree, the various activities directly and indirectly associated with the proposed pipeline project will be likely to result in significant relocation and concentration changes in the population of the regions, as well as in a net total increase. Depending upon how these situations are handled, what the attitudes of the local residents are at that time, and what one's opinion is of such a change, these changes might or might not have an adverse impact.

Larger concentrations of people in fewer communities could make possible better facilities of many types and improved social and economic conditions, but could also give rise to problems such as alcohol abuse, crime, loss of identity and cultural traditions, and overtaxing of the local environment for purposes of subsistence hunting and fishing. Changes in the local economy of a relatively large community in the northern region might result quite rapidly in a serious local unemployment problem.

A large concentration of people in one locality or total overpopulation of the Mackenzie Valley region will at some point overtax the game, fish and fur-bearing-animal potential of either the local area or the entire region. Unless proper restrictions are put in force, these types of population trends will have the effect of impoverishing or eliminating subsistence or recreational harvests of the game and fur resources. In certain areas the same will be true of the limited timber resources.

Land Use

Should the proposed project be adopted, the right-of-way (120 feet wide), the land occupied by borrow pits and quarries and by roads that served only the project, and the land occupied by compressor stations, communications sites, material marshalling areas, wharves, and the like, will be committed during the construction phase of the project. After construction has been completed much of the right-of-way and all temporary facilities, including borrow pits not needed for maintenance, will be available for non-pipeline-related uses. Right-of-way cleared through forested areas will not be available for timber production for the life of the project. None of the right-of-way will be available for surface mining; deep mining will not be affected.

Archeological and Historical Factors

Adverse effects on archeological resources along the proposed route will be inversely proportional to the extent and effectiveness of the archeological salvage program. Some unidentified sites will very likely be damaged or destroyed, but their number and value cannot be estimated. If salvage measures were not instituted, an understanding of cultural heritage in some areas might be permanently lost.

Although historic sites themselves will not be damaged by construction and operation of the proposed project, esthetic damage to the nearby landscape (clear-cut right-of-way through forested areas, cut and fill operations, compressor stations and other ancillary facilities) could detract from visitors' enjoyment and appreciation of such places.

Other possible adverse effects on archeological and historic sites include the loss of artifacts and fossils found on the surface, which might be carried away by project personnel and "arrowhead hunters", and vandalism to the relics of early mining, trapping and other history, which might result from improved public access provided by the proposed project. However, a certain amount of vandalism to archeological and historic sites is probably unavoidable at some point in the future, with or without the proposed project.

Recreation and Esthetic Factors

Outdoor recreation resources are closely related to the terrestrial and aquatic biotic resources which are discussed elsewhere in this section and elsewhere in the Statement.

In the regions traversed by the proposed pipeline north of 60° N latitude, the main adverse effect on recreation resources will be in the form of landscape scarring from construction of the pipeline and related roads, borrow pits, airstrips, compressor stations, communication sites, wharves, etc. Eventually some of these disturbances will be concealed by natural vegetation, while others will remain visible for decades, in spite of any rehabilitation and revegetation efforts that might be made. Other landscape scars will result if underlying permafrost thaws, causing settlement and erosion.

The proposed project by itself will have adverse effects on some wilderness areas, notably the Arctic coastal region, which will be eliminated from such a designation. Of greater importance will be the major invasion of wilderness set off by the proposed project. By its roads and rights-of-way it will make the land more accessible to those who would come later. It will also stimulate related development in transportation, recreation and industry, as does any large project. Other major projects will be undertaken, bringing about the invasion of wild lands by more men and machines.

Increased access to formerly remote areas and the resultant influx of people will cause environmental damage in the form of man-caused forest fires, landscape scarring by all-terrain vehicles, littering, over-fishing and so forth, thus adversely affecting the recreation value of land in its natural state. However, careful management could reduce the adverse impact of such an invasion on the fragile northern environment.

South of 60° N latitude, the proposed project will have only minor effect on recreation and esthetic resources because the route would parallel an existing pipeline right-of-way for large parts of the distance. Some loss of recreation quality will occur from noise, dust, smoke, road congestion, etc., in the immediate vicinity during construction of the proposed pipeline.

Air Quality

During the construction and maintenance phases there could be local, temporary deterioration of air quality caused by particulate and gaseous emissions from the engines of construction equipment and other vehicles. During testing and start-up operations some methanol and natural gas would reach the atmosphere, but would be dispersed so rapidly that there would be no noticeable effect on air quality. During the operational phase local deterioration of air quality could be caused by the operation of compressor stations. As natural gas, a clean fuel, would be used, the introduction of particulate and gaseous emissions would probably be minor in most cases. Gases toxic to plants, especially sulphur dioxide, could have a serious short-term cumulative effect on lichens in regions experiencing frequent temperature inversions.

Rupture of the pipeline would result in the escape of large amounts of natural gas to the atmosphere, but dispersion would be very rapid and there would be no short-term impact on air quality.

Environmental Noise

Noise pollution of the atmosphere would be unavoidable during the operational phase in the vicinity of compressor stations and along aircraft flight paths.

5.1.2.2 Summary of Residual Effects

Immediate Project Area

The adverse impacts of proposed project components will principally be one-time events and transitory in their effects upon both abiotic and biotic components of the environment. Commitment of a known amount of land for right-of-way and ancillary facilities will be a one-time use of this resource which will be available again for other uses with little foreseeable penalty at the termination of the proposed project. The use of mineral resources for construction materials will primarily be a one-time construction-phase feature but with some incremental, continuing utilization. All uses of materials will probably represent permanent commitments as there will be little prospect of their recovery without causing environmental damage.

Proper management of the project area by employing known mitigative measures could make most impacts short term and transitory in their effects. Since a refrigerated natural gas pipeline like the one proposed has never been constructed before, its effects on drainage and changed water regime of wetlands and creation of aufeis conditions in streams cannot be evaluated at present and have the potential of short-term, continuing threats to both terrestrial and aquatic environments.

Several adverse environmental effects will begin in the preconstruction phase, intensify during construction and continue for the duration of the proposed project. Vegetation and terrain disruption will not only bring about erosion and stream siltation but will degrade the esthetic quality of the landscape for many years. Incremental damages of this type will be a continuing threat both on the right-of-way and on adjacent terrain as a consequence of summer traffic necessary for emergency pipeline repairs.

Recurrent accidental discharge of fuel oils and chemicals will be a continuing threat to aquatic ecosystems and could entail poorly understood synergistic effects that could be extremely serious.

All significant impacts during operations will be continuing and might have incremental, cumulative and synergistic effects on the environment. In addition to terrain degradation and chemical pollution mentioned above, there will be all forms of wildlife disturbance resulting from human presence; hunting, aircraft, blasting, machinery and turbine noise, and deliberate harassment.

Through direct mortality, change in habitats, and effects on animal behavior there will be losses of some mammal populations from the project area. However, the area could also be an attraction to certain animals. Bears and foxes will probably suffer increased mortality in their conflicts with man. Caribou might be attracted by grazing opportunities resulting from revegetation of the right-of-way which also might be utilized by many other species as easy routes of travel. Grazing and travel by ungulates could reduce the effectiveness of erosion control procedures.

The short-term continuing threats to the environment will primarily consist of aircraft noise disturbance of animals, sport hunting consequent to improved accessibility, and toxic chemicals, including toxic gas emissions from compressor stations. While all of these are subject to a large measure of control it is to be expected that there will be significant, measurable, residual effects.

Regional Considerations

Adverse regional effects will be the intrusion on wilderness and the inevitable, incremental shrinkage of the amount of land in its natural state. A combination of adverse and beneficial effects will bring large changes to the economic, sociological and cultural attributes of the northern regions affected, as mentioned in Sections 5.1.2.1, 5.1.2.3 and elsewhere in this Statement. Evaluation of the costs and benefits to the resident peoples is a value judgment that only they can provide.

5.1.2.3 Impacts in Relation to Resources, Activities and Values

Resources

See sections 5.1.2.1 and 5.1.2.2.

Activities

It should be emphasized, relative to the following discussions of economic and social adverse impacts, that many of the activities that will be primary and secondary parts of the proposed pipeline project could have both good and bad impacts on the people and the economy. Few, if any, impacts are all good or all bad, and the resultant of these two aspects will depend upon how activities are handled by the Applicant and the local residents, what safeguards and regulations are established and enforced, what the prevailing attitude of the local residents is at the time, and what viewpoints or biases a particular observer might have toward socioeconomic changes.

Economic and Regional Development

The traditional pursuit of a land-related hunting, fishing and trapping economy will be adversely affected by the proposed introduction of large-scale opportunities for employment in a wage economy. The degree to which local residents will choose to participate on a full-time or part-time basis in wage employment and to continue in this employment will determine the immediate effect on a land-related economy. A trend away from a land-related subsistence economy is already established; whether this will continue through the next 20 or more years of projected pipeline activity will depend on a sufficient supply of wage-economy jobs and on the people's choice of lifestyle and economy. A free choice of either pursuit will be available to individuals, and with proper controls these two economies will coexist.

Economic pressures from the relatively short-lived construction phase of the proposed pipeline might result ultimately in adverse effects on business and service sectors of some communities. Optimistic expansion of facilities to accommodate peak demands for supplies and services might result in an infrastructure that could not be supported by the lower level of economic activity associated with the proposed operational pipeline phase.

Projections of the continuing viability of a wage-employment economy during the life of the proposed pipeline project are based in part on expected secondary effects of gas and oil exploration, development and production in the regions of the Mackenzie Valley adjacent to the proposed pipeline route. If sufficient economic reserves are not found, the resulting lack of job opportunities will have an adverse effect on the availability of jobs in the region for those already trained in gas-industry types of jobs.

The generation of considerable local income in the form of wages and payments for services and products will result from the proposed pipeline project, and this should have an overall beneficial effect. An adverse impact could be imposed on the local economy if a large percentage of the income were lost to the local economy through income leakage due to direct purchasing of goods and services from outside of the region.

Social

Adverse impacts on the family and communal social life and structure of some communities might result from improperly planned location of installations, roads and other transportation facilities close to isolated communities that have not been attuned to a commercial or wage-economy lifestyle. Adverse reactions might be manifested in resentment or hatred, alcohol abuse, family breakdown, or abandonment of essential subsistence hunting and fishing activities that could lead to greater poverty or dependence on welfare. It appears from opinions expressed by Native individuals, community representatives, and the Native ethnic organizations that a satisfactory settlement of their land claims is of foremost importance. Some adverse social impacts might be generated or accentuated, chiefly in larger, ethnically mixed communities, by inequalities inherent in social, educational and job experience backgrounds, by income-related differences in housing, and by a mutual lack of understanding of different ethnic-related lifestyles. Problems in these socioeconomic areas currently exist in several communities, such as Inuvik.

Adverse social and economic impacts might result, after the peak activity years of the proposed pipeline project when the potential employment level will decline, if measures are not taken beforehand to train and encourage individuals and local governing bodies in the principles of thrift and financial planning and to provide service facilities to support this. The concept of saving and planning ahead is almost unknown to the Natives, and there is great danger that when short-lived prosperity moderates or ends, their social structure will suffer a severe impact.

Recreational and Wildlife Refuges

Adverse effects on recreational pursuits will be in the loss of wilderness, scarring of the landscape and reduction of its esthetic quality, and all changes to the environment which might lead to short-term diminished stocks of fish and wildlife or which in the shorter term will force game animals into less accessible areas. Prohibition of hunting and fishing will be an adverse effect to recreation of construction workers.

One of the most critical adverse effects of the proposed project will be its invasion of wilderness and its crossing of wilderness and quasi-wilderness areas which have been recommended for protection, such as Canadian Arctic Wildlife Ranges in Yukon Territory and various IBP (International Biological Program) Ecological Reserves, which will be either crossed or threatened by proximity of the proposed pipeline.

Values

Social and Health

Impacts on social values are not amenable to generalizations. Social attitudes in the northern regions are currently in a state of flux. Differences of attitudes exist between regional groups, ethnic groups, community groups, age groups, and individuals within these groups. The current attitudes are not likely to obtain 10 to 20 years hence. Thus, some adverse impacts on social values of certain segments of the population are unavoidable, and by the same token beneficial impacts will be realized by others. Many of the two-edged social impacts that might result from the proposed pipeline project will fall in the categories of subsistence vs. wage employment, urbanized vs. isolated community life, ethnic integration vs. segregation, and loss of cultural and language identity.

Impacts of the proposed project on health conditions in the regions will be expected to be only beneficial. Adverse impacts could result, however, if proper planning and controls were not effected by both the Applicant and the government agencies concerned. A factor, related to improved health and sanitation, that should be considered is the longer term effect of an increasing population. Overpopulation in the northern regions could have a distinct adverse impact because of the environmental limitations. The current life-expectancy in the North is much lower than in southern Canada, owing largely to inadequate health care and sanitation practices, and old age is the least important cause of death. Certainly better health care and conditions are desired and should be encouraged regardless of whether any major commercial development occurs, but it should be anticipated that a greatly accelerated rate of population growth is apt to occur as improved health education and care cut the mortality rate.

Esthetic, Historic and Recreation

Esthetic values will be adversely affected in variable degrees over the entire proposed route. This will be an unavoidable cost should the project be approved, but other than for the effect on wilderness the impact will be considered minor by many. The visual effect could be mitigated in forested areas except in the aerial view, but in the Tundra and Forest-Tundra, scars will be evident long after termination of the proposed project.

There will be no known loss to historical values since historic sites will be avoided and archeological salvage will in large degree protect against the loss of man's cultural record. Although there could be some unavoidable losses, the proposed project could have a positive effect in locating and providing study opportunities of sites previously unknown.

Recreational values will be negatively affected by losses of wilderness qualities and long-term increases in hunting and fishing pressure but the latter will be only a minor impact attributable directly to the proposed project. To many people seeking recreation the effect will represent a positive gain in making recreation resources of many kinds more readily accessible.

6 RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF THE ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITIES

6.1 ARCTIC GAS PIPELINE PROJECT

6.1.2 Canadian Pipeline

6.1.2.1 Definitions of "Long Term" and "Short Term"

For the purposes of this Statement, "short term" is generally taken to mean the lifetime of the proposed pipeline system, but some so-called "shorter-term" uses and effects are also discussed. For example, a distinction can be made between the impacts occurring during the construction and operational phases of the proposed project. "Long term" is generally taken to mean that time beyond the lifetime of the pipeline system; however, it is used in a relative sense and therefore varies somewhat depending upon the environmental component being discussed. In some cases, "longer term" is used to mean several human generations beyond the lifetime of the pipeline system.

6.1.2.2 Environmental Values Affected by the Proposed Action

Climate

If the proposal were adopted, any direct regional impacts, either short-term or long-term, on the climate would be so minor as to be unrecognizable.

Topography, Geology, and Soils

The long-term productivity of the area would generally not be enhanced or maintained by the short-term use of the local environment as a pipeline corridor.

Many of the changes in topographic and geologic conditions that would be brought about by the proposed pipeline would have short-term effects on the environment, but would not have appreciable long-term effects. At least in the non-permafrost areas that comprise about 50 percent of the proposed route, scars on the terrain would heal shortly after the pipeline was abandoned, and in some cases, such as borrow sites, possibly while the pipeline was still in use. Effects such as sedimentation of streams and accelerated erosion generally would be shorter term.

There are, however, some long-term effects. Foremost among these would be the consumption of the natural gas transported by the pipeline. The later use of this gas, perhaps in a more valuable way, would be precluded. The gravel and other natural construction materials that would be used by the project could theoretically be reclaimed. Much of the borrow, however, would be distributed in such a way that it would not be feasible to recover it.

Slope modifications caused by landslides that might be initiated by construction of the pipeline would be longer-term effects as would effects caused by permafrost thawing.

Water Resources

The primary consumption of both surface and ground water would have shorter-term effects. The amount of water required for operation and maintenance of the pipeline would be small in comparison to the amount available, and thus there would be no short-term or long-term effects.

Increase in suspended and bedload sediment would primarily occur during the shorter term. Proposed erosion control measures should reduce short-term channel and upland erosion; there should be no long-term effects.

Although there is potential for impact on water quality because of waste disposal in areas that are now uncontaminated, the use of secondary treatment methods and sewage lagoons could prevent serious alterations to the short-term or long-term quality of water resources.

Vegetation

No significant changes in plant communities would be induced by the proposed project, assuming the probable success of mitigating measures available to the Applicant. The short-term effect would be the commitment of the acreage of the right-of-way, permanent roads, airstrips, yarding sites, borrow pits, compressor stations and other facilities to project use and to vegetation change varying from total destruction to minor disruption. In terms of the large areas of all kinds of plant communities, the losses by short-term use of required acreage would be small and no community type would be threatened.

The shorter-term effects would include destructive practices of tree and tall-shrub removal, disruptions to the insulating moss-peat mat and compression of this mat where not otherwise damaged. Recovery of lightly damaged areas would take place in the shorter term and revegetation programs would initiate erosion control that would be continued by natural succession of native communities. The short-term effects on the right-of-way in forested areas would be the prevention of the regrowth of trees and tall shrubs.

In the long term, following abandonment of the proposed project, all vacated and abandoned areas would be expected to recover fully and develop natural communities typical of specific geographic regions.

Effects off the right-of-way would be the result of drainage changes, overland summer travel to meet emergency situations, soil erosion and fire. Drainage alterations could be long enduring on side slopes but the effect would be change of one community type to another with no significant overall loss. Erosion controls could be expected to prevent short-term vegetation change. The impact of use of cross-country vehicles and machinery would depend upon the frequency and season of use. Individual events would be subject to correction and community recovery in the short term and there should be no long-term impact.

Effects would be adverse to all vegetation on right-of-way and other occupied land areas in the shorter-term and to forest vegetation for the duration of pipeline operations. Off the right-of-way, but adjacent to it in forest areas, productivity might be increased by creation of the "edge effect" between communities. Greater diversity of plant species and increase in plant biomass would enhance the diversity of wildlife habitat and animal populations. Such increased productivity would be a short-term benefit to some populations and a trade-off for the loss of forest and its characteristic animal populations. In the long term the process of community succession would restore equilibrium states of productivity characteristic of different communities before disturbance.

Wildlife

Fish

Shorter term effects of the proposed project would principally be siltation of spawning beds, depletion of oxygen in over-wintering lakes and streams, blockage of migration, introduction of toxic chemicals and facilitation of human access to sport-fishing stocks. Control of erosion would hold siltation to the shorter term, in most areas, but side-slope instability in some areas of ice-rich permafrost would extend this problem into the short term or beyond. High turbidity levels in the shorter term could seriously diminish the biological productivity of the entire aquatic ecosystem, although short-term recovery would be probable.

Rigorous control over discharge of organic wastes and toxic chemicals into streams and lakes could avoid the threat of oxygen depletion and poisoning of plants and animals. Accidental discharges of fuel oil and toxicants are possible and their effects could be adverse, chronic and cumulative. The effects of such pollution would be short-term degradation of the environment of fish and the entire ecosystem of which they are a part. The productivity of the Mackenzie River drainage, and especially the biologically-rich Mackenzie Delta, would be potentially threatened during the short term. The short-term effects of toxic materials would depend upon the actual magnitude of shorter-term effects. It is conceivable that full recovery would not occur in the short term, but certainly would in the long term.

Human access to fishing resources, either for sport or commercial fishing, would be a minor concern insofar as construction or operation of the proposed pipeline is concerned. The greater number of people who would follow, more as a consequence of highways independently constructed, would pose a long-term threat to fishing stocks and to subsistence fishing of Native peoples.

Mitigating measures could prevent, control or correct most of the shorter term effects on fish, but during the short term there could be threats of unpredictable magnitude to some aquatic ecosystems. Maintenance of productivity in some cases would be improbable and in no case is any enhancement of the environment or increased productivity of fish foreseen.

Mammals

The productivity of mammal populations would be altered in some cases by habitat changes following possible fires, forest clearing, drainage of wetlands, or deprivation of wetland water supply by upslope disruption of drainage and impoundment of water. Such changes would favor one group of species over another and would represent trade-offs which many would consider desirable. Overall productivity might be enhanced; for example, the plant communities following forest fire provide increased range and browse for moose.

Construction in the winter season would avoid contacts with caribou and, beyond shorter-term displacement of animals significantly affected by noise, would have little impact on other species. Avoidance of Dall sheep range and denning sites of arctic fox and grizzly bears and strict enforcement of a ban on hunting of all species would mitigate some of the more critical potential impacts.

Noise sources such as compressor turbines and uncontrolled aircraft could have short-term effects on caribou during calving and cause range displacement of bears, wolverine and Dall sheep.

Mitigating measures could reduce short-term impacts to levels which would permit the maintenance of natural mammal productivity. The greatest threat to continued productivity in the shorter term would be either uncontrolled or illegal hunting. Increased access to legal hunting in the short term could adversely affect bear and Dall sheep and possibly caribou. Accessibility would be more the result of public roads planned for the region than of the pipeline roads, on which access could be controlled.

Birds

Construction and operation of the proposed route would be a major threat to the large populations of waterfowl and shorebirds that nest, molt, rest, feed and stage along the Arctic coast and major river systems. Mitigating measures, such as winter construction, would avoid contact with migrating populations during the shorter term. During the short term, aircraft disturbance to birds would be severe without controls and uncertain in total effect even if recommended altitude and flight paths were maintained.

By proper scheduling, route selection, and avoidance of harassment the short-term productivity of bird populations could be maintained. This applies also to raptors, including the endangered peregrine falcon, whose habitat could be avoided and to which only human presence and molestation would be a disturbing factor.

The proposed project would provide no enhancement of bird productivity but, on the assumption of the success of mitigating measures, could permit its maintenance. Even though certain species of birds would be affected adversely locally, the probability is low that the overall productivity of all kinds of bird populations over the length of the proposed route would be affected significantly during the short term.

Recreation and Esthetics

Various impacts during the construction and operational phases of the proposed project, including landscape scarring and compressor station sites with their associated noise and possible air pollution, would have short-term effects on the recreation use of the area. Wilderness can be used by man and still retain its long-term productivity as wilderness if the use is not too disruptive or permanent. The proposed pipeline would destroy wilderness values within the construction zone during the short term, but afterwards much of the land could be restored to its natural state.

Air Quality

The operation of compressor stations and of equipment and vehicles powered by internal combustion engines would cause minor short-term localized atmoshperic pollution. Compressor station exhaust gases would contain nitrogen oxides (up to 34 pounds per hour), sulfur oxides (maximum 9.38 pounds per hour), carbon monoxide (up to 4.66 pounds per hour) and unburned hydrocarbons (up to 9.32 pounds per hour).

6.1.2.3 Restrictions to Future Options and Needs

Land Use

The right-of-way and land occupied by ancillary facilities would be unavailable during the shorter term if the proposal were adopted. During the short term much of the right-of-way would be available for other uses, some of which, such as wildlife habitat, pasture or farmland, would be the same as the uses before initiation of the project. Long-term productivity would be unaffected except that some pipeline-related facilities could be put to other uses and that construction-material sites used as borrow pits and quarries might be so depleted as to have no value as future sources of such material.

Short-term adverse impacts on recreation resources and general productivity of the environment would result if the proposed project caused permanent damage to sport fisheries or game animals. Shorter-term disruption of drainage systems could cause long-term damage to scenic streams and waterfalls along the route, affecting public appreciation of the region. Long-term effects on wilderness would be related mainly to improved access and the resultant influx of people using the area for recreational activities. Most of these effects would be adverse. Construction of the proposed project would probably encourage further development in the Canadian northwest and thus further disruption of the Canadian wilderness. Increases in population would also increase the pressures on wilderness and recreation resources. However, proper planning could help to minimize the impact of future development on wilderness areas.

Acquisition of Mineral Resources

Implementing the proposed project probably would have little direct short-term or long-term effect on the development of metallic, nonmetallic, or coal mining operations; however, it could accelerate exploration and discovery of additional reserves of oil and gas in northwestern Canada. The availability of low-cost gas fuel could be an incentive to development of an iron-ore reduction plant, but would not be of prime importance to zinc or lead smelters.

Availability of Fuel

Should the proposed pipeline be constructed and operated, a large quantity of natural gas (estimated to be more than 26 trillion cubic feet) would be delivered and consumed during the short term; it would therefore be unavailable for long-term use. The existence of the pipeline, however, could undoubtedly accelerate exploration and discovery of additional reserves of oil and gas in northwestern Canada.

6.1.2.4 Benefits of Energy Supply Made Available as a Result of the Proposed Action

Numerous economic and social benefits would accrue from a plentiful supply of relatively cheap and clean energy. Most of these benefits would be of a short-term nature and would affect the populations in the conterminous United States and southern Canada more than the Native peoples and others in the immediate project area; however, a Canadian government objective will be to ensure that the maximum possible benefits will be received by the northern residents. The major benefit would be a short-term decrease in dependency on energy sources which are subject to politically motivated interruption. At best, in the short term, the proposed pipeline would forestall critical shortages of fossil hydrocarbon resources, perhaps providing more time for the development of alternative energy sources and substitutes for petrochemical feedstocks.

7 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES IF THE PROPOSED ACTION IS IMPLEMENTED

7.1 ARCTIC GAS PIPELINE PROJECT

7.1.2 Canadian Pipeline

7.1.2.1 Damages from Natural Catastrophe or Man-Caused Accidents

A natural catastrophe or man-caused accident could result in rupture of the proposed pipeline followed by explosion and fire. Few if any irreversible or irretrievable commitments of resources would occur in the surrounding biotic or abiotic systems strictly as a result of explosion and fire but a quantity of natural gas would be burned or vented to the atmosphere. If the pipeline block valves closed automatically in response to pipe rupture, the quantity of gas irretrievably lost would be no greater than that contained within approximately 20 line miles of pipe.

In the haste to repair a line break--particularly in summer--some components of the surrounding ecosystem could be damaged, thus comprising irreversible and irretrievable commitments. The principal effects would be in the portions of the proposed route underlain by permanently frozen ground and would include destruction of vegetation and terrain damage leading to thaw of the permafrost by heavy repair equipment moving to the line break.

7.1.2.2 Project Structures Unlikely to be Removed

At the end of use of the proposed pipeline, the Applicant indicates that with one exception, all facilities would either be salvaged and removed or dedicated to alternative uses (CAGPL, 1974b, 14.d N, 6.5, p. 12). The exception would be the buried pipeline. Leaving this pipe in the ground would irreversibly and irretrievably commit approximately 2.18 million tons of steel pipe (CAGPL, 1974a, 13.a.3.1, fig. 2).

7.1.2.3 Resource Extraction

The proposed project would commit to short-term utilization the discovered and undiscovered gas resources of northern Alaska and northwestern Canada. The Applicant's latest estimates of proven recoverable or salable gas reserves are approximately 22.5 trillion cubic feet at Prudhoe Bay in northern Alaska and 3.9 trillion cubic feet in the MacKenzie Delta area in northwestern Canada. The total undiscovered gas resources cannot be reliably estimated but probably will amount to at least a similar volume. Thus implementation of the proposed project would irreversibly and irretrievably commit to use gas equivalent to a few years' total consumption (at current rates) in Canada and the United States. Approximately 6 percent of the gas produced would be consumed by the proposed pipeline system, principally in powering compression and refrigeration stations (Table 1.1.2.1-1, this Statement).

Natural construction materials (sand, gravel and stone) amounting to about 30 million cubic yards would in general be irreversibly and irretrievably committed to the proposed project. Some materials placed above the ground possibly could be recovered for reuse after conclusion of the project.

7.1.2.4 Erosion

The principal impacts from erosion would be 1) extraction of sand and gravel from stream channels, from sites near channels, and from hillside borrow pits; 2) altered landscape features resulting from construction activity; 3) induced accelerated erosion including thermokarst developments; and 4) altered microdrainage patterns within and adjacent to the pipeline area. These impacts would also affect the short-term water-related environment. However, it is doubtful that any commitments of the water resources to the short term would be considered as irreversible and irretrievable.

Erosion would cause major shorter-term and some potentially moderate short-term turbidity increases in streams and lakes, as well as sedimentation of spawning beds and fish overwintering areas. Mitigative measures should control short-term changes of these types and there would be no irreversible or irretrievable effects on aquatic ecosystems.

7.1.2.5 Destruction of Cultural, Archeological, Esthetic, Scenic, or Historic Sites

It is likely that some unidentified archeological or historic sites would be damaged or destroyed during construction of the proposed project, but their number and value cannot be estimated. Archeological evidence is a very limited and irreplaceable resource. It is easily destroyed and once gone, is lost forever.

Although historic sites themselves would not be damaged by construction and operation of the proposed project, esthetic damage to the nearby landscape in the form of alterations of the natural topography could detract from visitors' enjoyment and appreciation of such places.

7.1.2.6 Irreversible and Irretrievable Commitments of Resources

Wildlife

When species' habitats are greatly reduced, remnant populations are restricted, localized or spread so thin geographically that they are vulnerable to extermination by natural causes, chance conditions or human actions. Habitats may be degraded by various land uses and by pollutants such as spills of oil and other substances that are directly or indirectly toxic. Certain pesticides can pass through food chains to kill wildlife, or as in the case of the peregrine falcon, disrupt reproduction processes. Materials such as oils and detergents can affect the insulating and waterproofing properties of the plumage of birds and the pelage of mammals, thereby greatly reducing their productivity and chances for survival. Species that are rare, restricted in distribution or physiologically (even psychologically) inhibited can become vulnerable to extermination. Natural populations may reach a theoretical threshold, beyond which the loss of a single breeding pair dooms the population unless it is artificially aided and rigidly protected. In the United States the peregrine falcon has reached this threshold already; in Canada its status is precarious.

Wildlife is a renewable resource dependent for survival on adequate suitable habitat. An irreversible and irretrievable change takes place when populations can no longer sustain both consumptive and non-consumptive pressures. This is the major problem in wildlife management and is the basis for concern for such arctic mammals as the polar bear, grizzly bear, wolf and wolverine and for birds such as the snow geese and diving ducks along the Beaufort Sea coast.

No specific irretrievable loss of wildlife that would be attributable to the proposed pipeline has been identified. If precautions taken to minimize disturbances, to avoid polluting the environment, and to reestablish vegetative cover were effective there should be no such losses. As some accidents must be expected, however, potential would exist for an accident that might affect a large enough segment of the range of a sensitive species to constitute an irretrievable and irreversible impact.

7.1.2.7 Irrevocable Changes in Land Use

Recreation and Esthetics

Construction of the proposed pipeline would have irreversible and irretrievable effects on outdoor recreation and esthetic resources along the proposed route. Landscape scarring and disruption of the natural scenery would last at least the life of the project, and in some areas, particularly the Arctic coastal region, the visual impact of the proposed project would remain much longer. This would be an irreversible commitment of one aspect of the resource that recreationists use.

The indirect effects of increased human population in the region, and increased human intrusion on wilderness areas would be irreversible impacts on existing recreation resources. Changes in existing patterns of human use and resource allocation stimulated by construction of the proposed project could irreversibly change the frontier wilderness of the Canadian Northwest, thus impairing part of its appeal to outdoor recreationists.

7.1.2.8 Commitments of Materials and Human Resources

Materials and supplies that would be irreversibly and irretrievably committed during construction of the proposed pipeline system are listed in Table 7.1.2.8-1. A total of 621,450 tons of materials and supplies would be required, of which the largest proportion by weight would be fuel, cement and reinforcing steel. This is in addition to pipe (Section 7.1.2.2) and construction materials (Section 7.1.2.3).

Through its 4-year construction phase the proposed pipeline project would provide as many as 6,500 jobs at the peak of activity. About 3,500 of these jobs could be filled by territorial residents if they were qualified and if they wished these types of employment. In its operational phase the proposed project would make available only about 200 permanent jobs during the lifetime of the pipeline.

In the shorter term, construction jobs could provide cash wages to most of the employable Native peoples under 30 years of age. In reality, however, probably no more than half of the available jobs would be filled by local recruitment because of conflict with demands for the Native work force in other activities such as firefighting, highway construction, community projects, hunting, and trapping. The wide geographic distribution of both the potential workforce and the job locations probably would deter many territorial residents from interest in pipeline-related job recruitment. Most non-Native and currently qualified native individuals are already fully employed, so that when some are lured from their present jobs by the high wages of pipeline-related jobs other (unemployed) Northerners will be able to take the previous jobs. Exceptions would be those who completed the training programs already initiated, and planned to be extended, by the

Table 7.1.2.8-1 Construction resource requirements, in tons

Fuel and lubricants for construction equipment, power generation and heating	375,000
Equipment repair and replacement parts	22,000
Welding supplies	3,900
Explosives	10,500
Fertilizer and seed for right-of-way revegetation	10,000
Foodstuffs for construction crews	17,100
Cement and reinforcing steel	155,000
Methanol	25,000
Lumber	2,950

Source: CAGPL, 1974, 13.a.5, fig. 2

Applicant. Shorter-term impacts of the proposed project on aspects of territorial life would be an infusion of cash into the economy by wages to the people directly employed and, through the multiplier effect, by increase in the provision of goods and services. The social impact would be an increase in the number of people converted to a wage economy.

Short-term impacts of the proposed project would be slight compared with the expectable effects of other changes in the Northland that would at most be only slightly accelerated by the proposed pipeline. Already the trend is for young Natives to enter the wage economy rather than to participate in traditional subsistence activities, making inevitable the irreversible commitment of human resources to wage employment, regardless of potential pipeline-related employment.

REFERENCES

Canadian Arctic Gas Pipeline Limited, 1974a, Construction plan (section 13.a) and Operations and maintenance plans (section 13.b): An exhibit in support of application to the Dept. of Indian Affairs and Northern Development of the Government of Canada for authorization to use land, and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities.

Canadian Arctic Gas Pipeline Limited, 1974b, Environmental statement (Canada-north of the 60th parallel): an exhibit in support of application to the Dept. of Indian Affairs and Northern Development of the Government of Canada for authorization to use land, and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities.

8 ALTERNATIVES TO THE PROPOSED ACTION

8.1 ALTERNATIVE GAS PIPELINE ROUTES

8.1.2 Canadian Pipeline

The Applicant, Canadian Arctic Gas Pipeline Limited, has proposed a large-diameter natural-gas pipeline from the Alaska-Yukon border through Canada (Section 1.1.2) to the conterminous United States (with a supply line, the Richards Island Supply Line, from the Mackenzie Delta, Northwest Territories). The existing environment through which the pipeline would pass in Canada is described in Section 2.1.2, and the potential environmental impacts are evaluated in Section 3.1.2. Ten routes and corridors are suggested as alternatives to parts of the proposed route (Figures 8.1.2-1 and -2): (1) Interior Route, (2) Cross-Delta Route, (3) Babbage Bight Corridor, (4) Fort Yukon Corridor, (5) Fairbanks Corridor (6) Haines Option Corridor, (7) Offshore Corridor, (8) Wolf Lake Corridors, (9) Dome Corridor, and (10) Brandon Corridor. Each major trunk line would include an alternative supply line from Richards Island in the Mackenzie Delta. Routes include alignments specified by the Applicant; corridors, where divergent from the proposed route, are broader linear zones within which alignments could be, but have not been, selected.

The proposed route would enter Canada at the Alaska-Yukon border north of the Brooks Range, receive a feeder line from the Mackenzie Delta, N.W.T., and divide into two delivery lines about 50 miles northwest of Calgary, Alberta. These two branches of the proposed route would deliver gas at the Saskatchewan-Montana and British Columbia-Idaho boundaries.

The Interior Route would enter Canada from Alaska south of the Brooks Range and join the proposed route, at Milepost 430 of the Prudhoe Bay Supply Line approximately 5 miles north of Fort McPherson. From this point the Interior Route would be identical to the proposed route. The Interior Route has been studied in detail commensurate with that for the proposed route, and will be proposed by the Applicant in the event that the proposed route is not available. (CAGPL, 1974e, 1.1, p. 1).

The Cross-Delta Route would diverge from the proposed route near Milepost 291, about 95 miles east of the Yukon-Alaska border. It would run north of the proposed route to the Beaufort Sea coast and across the Mackenzie Delta before joining the Richards Island Supply Line. Two realignments also would be required. Through the area in which they diverge, the length of the Cross-Delta Route would be 138 miles shorter than the proposed route.

The Babbage Bight Corridor is coincident with the proposed route to about Milepost 291, where it would connect with the Cross-Delta Route which it would follow eastward to Richards Island. This system would be completed by a 15-mile lateral northward to the arctic coast near the mouth of Babbage River, Y.T., where a marine terminal would be constructed for transshipment of liguified natural gas (LNG). The impact of LNG transshipment is discussed in the Alternatives volume of this report.

The Fort Yukon Corridor enters Canada at the Alaska-Yukon border 65 miles northwest of Dawson and extends southeastward to join the proposed route at Main Line Milepost 1265 near Windfall, Alberta. From this point the Fort Yukon Corridor would be identical to the proposed route. A feeder line, the Richards Island Supply Line, would extend south from the Mackenzie Delta to join the Fort Yukon Corridor east of Dawson.

The Fairbanks Corridor follows the Alaska Highway from the Yukon-Alaska border eastward to join the Fort Yukon Corridor near Watson Lake, Y.T. Southeastward from this point, the Fairbanks Corridor is identical to the Fort Yukon Corridor to Windfall, Alberta, and then coincident with the proposed route. The Richards Island Supply Line would extend south to join the Fairbanks Corridor near Whitehorse, Y.T.

The Haines Option Corridor is identical to the Fairbanks Corridor from the Alaska-Yukon border to Haines Junction, then extends from Haines Junction south to Haines. This system would extend south into Alaska to terminate at a marine port from which liquefied natural gas (LNG) would be shipped (see Alternatives volume). The Haines Option Corridor is described in conjunction with the Fairbanks Corridor throughout this Section.

The Offshore Corridor is an alternative to the proposed route, and is chiefly in Alaska. Because it is coincident with the proposed route in Canada except for 20 miles in the northwest corner, the Offshore Corridor is mentioned in this Section. Further information may be found in the Alaska volume.

The Wolf Lake Corridors extend for 2,841 miles; they are identical to the proposed route from the Alaska-Yukon border and Richards Island to Main Line Milepost 684 (near Fort Simpson). From this point, the Liard River-Wolf Lake Corridor leaves the proposed route and extends to Wolf Lake Junction in east-central Alberta, where it divides into two delivery line corridors. One, Wolf Lake-Emerson Corridor, heads southeastward to the U.S. border, where it would join the Red River Corridor. The other, Wolf Lake-Crowsnest Corridor, heads southwestward, joins the Kingsgate Delivery Line at Milepost 173, and then follows it to the U.S. border.

The Dome Corridor would serve as an alternative to the Monchy Delivery Line. It would extend from Milepost 234 to near Keystone, Saskatchewan (Moose Jaw Segment), and then continue southeastward to Elmore, Saskatchewan (Dome Segment), at the U.S.-Canada border, where it would join the Dome route.

The Brandon Corridor would also serve as an alternative to the Monchy Delivery Line. It would be coincident with the Dome Corridor from Milepost 234 to near Keystone, Saskatchewan (Moose Jaw Segment), where it would continue eastward (Brandon Segment) to join the Wolf Lake-Emerson Corridor (Treherne Segment), and then extend to Emerson, Manitoba, at the U.S.-Canada border. Here it would join the Red River Corridor.

In this section of the Environmental Impact Statement, these alternatives are discussed in terms of the existing environment and evaluated as to potential environmental impacts should a gas pipeline follow each of them. Also, the impacts of using the proposed route and the alternatives are compared (Section 8.1.2). The possible impacts of transportation modes other than pipelines are discussed in the Alternatives volume of this Statement. The alternative of no action is discussed in the Overview volume.

8.1.2.1 Interior Route

The Interior Route is identical to the proposed route except for one segment that is an alternative to part of the Prudhoe Bay Supply Line of the proposed route. Only this alternative segment is discussed here. It crosses the Alaska-Yukon border at Milepost 297 and extends for 178 miles to Milepost 475, about 5 miles north of Fort McPherson, where it joins the proposed route at Milepost 430 of that route.

Description of the Existing Environment

Climate

The data available do not suggest significant climatic differences between the areas traversed by the Interior Route and the proposed route (Section 2.1.2.1). Winter temperatures near Old Crow are probably a few degrees colder than those at the same latitude on the proposed route. Snowfall and total precipitation near the Yukon-Alaska boundary are less than in the Mackenzie Valley, but the amounts of both are so small that the differences probably are not important.

Topography

For the purpose of description the 178-mile Interior Route (Figure 8.1.2.1-1) can be subdivided into three divisions--Old Crow Basin, Richardson Mountains, and Lower Mackenzie Valley. Additional information on the topography of the route is presented below under Physiography.

The route traverses the Old Crow Basin between the Alaska-Yukon border, Milepost 297 and the crossing of Berry Creek, Milepost 387. In the first 23 miles, it crosses Potato, Surprise, and Schaeffer Creeks and the intervening well-rounded ridges along the northern edge of the Old Crow Range. Elevations vary from 1,100 to 2,300 feet above sea level. Between Mileposts 320 and 325, it skirts the northern edge of the Old Crow Range and the southern limit of the Old Crow Flats. Mountains to the south reach 3,000 to 4,000 feet in height. Numerous thermokarst lakes dot the landscape to the north. Between Mileposts 330 and 360 it crosses the undulating well-drained Old Crow Plain, bordered on the north by numerous thermokarst lakes and on the south by the well-entrenched Porcupine River. The crossing of the Old Crow River, Milepost 333, is 7 miles north of the settlement of Old Crow. Elevations along this segment of the route range from 1,100 to 1,300 feet, with local relief rarely exceeding 50 feet. Between Mileposts 360 and 387, the route would be within 6 miles of the north bank of the Porcupine River, crossing the Driftwood River at Milepost 370, Rat Indian Creek at Milepost 374, and Berry Creek at Milepost 387. Elevations along the route vary between 1,000 and 1,400 feet, with local relief in the order of 100 feet.

The Interior Route would traverse the west flank of the Richardson Mountains between Berry Creek, Milepost 387, and the drainage divide of the Richardson Mountains along the Yukon-Northwest Territories boundary, Milepost 438. The Bell and Rat Rivers as well as numerous intermittent tributaries of the Porcupine and Bell Rivers would be crossed between Mileposts 387 and 417. Elevations range from 1,000 feet to 1,400 feet across undulating low foothills. Local relief is generally less than 500 feet. The route would pass some 2.5 miles north of the settlement of Lapierre House at Milepost 413.

Ascending the western flank of the Richardson Mountains over the next 21 miles, the route would climb sharply upward for 3 miles from the Bell and Rat River crossings, cross more rugged foothills at elevations between 1,500 and 2,100 feet from Milepost 420 to 427, and drop sharply into the Rat River valley at Milepost 429, elevation 1,600 feet. It would then climb, during the next 7 miles, along the Rat River and a tributary to an elevation of 1,900 feet (Milepost 436). Peaks on either side of the route reach 3,500 to 4,000 feet. Over the next 2 miles, the route would climb 700 feet to the summit of a pass in the Richardson Mountains, Milepost 438, elevation 2,700 feet. Peaks of the Richardson Mountains in this area reach elevations of 3,000 to 4,000 feet.

In the first 4 miles that the route descends the east flank of the Richardson Mountains, it generally follows a tributary of Stony Creek from Milepost 442, elevation 2,000 feet, to Milepost 448, elevation 1,400 feet. At this point, the route would veer northward, then turn easterly, cross a sharp ridge at Milepost 450, and drop onto the plateau near Milepost 452, elevation 1,600 feet.

Over the next 16 miles, the Interior Route crosses the Peel Plateau of the Lower Mackenzie Valley, dropping gradually from 1,600 to 800 feet at Milepost 468. In the next mile, it would drop 600 feet off the Peel Plateau onto the Peel River terrace. The remainder of the route from Milepost 469 to 475, drops gradually from 200 to 75 feet above sea level as it threads its way between numerous small lakes to the junction of the Interior and proposed route, approximately 1.5 miles west of the Peel River crossing. This junction would be about 5 miles north of Fort McPherson.

Geology

For the purpose of description the Interior Route is subdivided into the Old Crow Basin, the Richardson Mountains, and the Lower Mackenzie Valley. Information used in this description was obtained largely from Krinsley and others (1971), Bostock (1948, 1967), Gabrielse (1957), and reports submitted by Alaskan Arctic Gas Pipeline Company (1974) and Canadian Arctic Gas Pipeline Limited (1974c, 1974e).

Physiography

In the vicinity of the Alaska-Yukon border the Interior Route traverses the Old Crow Range. The mountain ridges are rounded, widely spaced and irregular in plan but trend in a general north-south direction. They rise and fall along gentle crest lines at elevations of 2,400 to 4,000 feet. Farther east, the route crosses the southern edge of the Old Crow Plain, a great, flat basin covered with lakes and ponds that occupy probably more than 30 percent of its surface. Except along the banks of large streams and a few suitable areas the plain is nearly treeless. Moss covered banks of muck (rotted vegetation and silt) 10 to 20 feet high, lie along the shores of many of the lakes. The Old Crow River and its main tributaries meander in valleys entrenched 60 to 125 feet below the level of the plain. Along the Interior Route, between the lakes on the north and the entrenched Porcupine River on the south, the plain is undulating and well drained.

The Richardson Mountains are a north-south-trending, folded mountain range about 160 miles long. Their widths range from 15 miles in the south to 50 miles in the north. The topography is relatively mature; slopes are controlled chiefly by dips of strata and by joints roughly perpendicular to bedding. Many of the broad, open valleys are underlain by relatively soft rocks. Narrow, deep valleys that trend across the structure are V-shaped. For most of their length the mountains form the divide between the drainage areas of the Porcupine and Peel Rivers. Stream directions within the mountains are largely controlled by structure but elsewhere a dendritic pattern prevails.

The western foothills of the Richardson Mountains are drained by small tributaries flowing into the Porcupine and Bell Rivers. These tributaries are swift flowing streams, up to 100 feet wide and 2 to 6 feet deep. They are in shallow valleys with stream banks 4 to 20 feet high. The tributaries on the west side of the Richardson Mountains are in broad, open valleys. These swift, gravel-floored streams are up to 100 feet wide and 1 to 4 feet deep, with banks 2 to 20 feet high. Several small lakes, the result of poor drainage due to permafrost, lie along the headwater streams in the mountains.

The remainder of the Interior Route, between the summit of the pass in the Richardson Mountains, Milepost 438, and the junction of the Interior and proposed routes, Milepost 475, crosses the portion of the Lower Mackenzie Valley Physiographic Division which includes the east flank of the Richardson Mountains, the Peel Plateau, and a portion of the Peel River terrace.

The east side of the Richardson Mountains rises abruptly from the Peel Plateau. Relief is from 500 to 1,700 feet and slopes are 50 to 100 percent. Locally, vertical scarps are present.

The Peel River has cut a steep terrace-face along the eastern edge of the Peel Plateau. Between the river and Fort McPherson the plateau rises to an elevation of over 1,200 feet in 3 miles. Between Rat River and Stony Creek the plateau is cut by numerous, steeply incised stream channels. The plateau rises gently to the Richardson Mountains.

Bedrock

From the Alaska-Yukon border (Milepost 297) to Milepost 360, bedrock is mainly argillite, quartzite, sandstone, and granite. East of the Old Crow River, shale and chert of Carboniferous and Permian age are dominant (Canada Geological Survey, 1963).

Upper Cretaceous clastic rocks with thin coal seams overlie granite in the area around Driftwood River. About 15 miles east of Old Crow the route is on mildly metamorphosed volcanic rocks. This fault-bounded block of basic volcanics stands above the surrounding Cretaceous rocks.

From approximately 10 miles east of the Driftwood River to the axis of the Richardson Mountains uplift, the structural pattern of the intervening rocks is that of a broad north-south trending trough. The route crosses successively younger clastic rocks (Permian, Jurassic, Cretaceous) until the axis of the trough is reached near the Bell River, where uppermost Lower Cretaceous shales occur. Folding and faulting of north to north-northeast trends are common in this area, and some east-west faulting also occurs.

The Richardson Mountains consist of folded, nonvolcanic, sedimentary rocks ranging in age from Precambrian to Late Cretaceous. Intrusive and highly metamorphosed rocks are absent. The major structural elements are symmetrical, northerly-trending folds, generally with gently plunging axes. Most of this section of the route lies along a broad zone of folded and faulted limestone, much of which is cherty. In the western 10 miles, the route crosses quartzite, sandstone, and black shale of Upper Jurassic and Lower Cretaceous age. Between the Porcupine and Bell Rivers these beds are covered by Tertiary sand and clay (Gabrielse, 1957).

The bedrock of the Peel Plateau is dominantly flat-lying to gently dipping shale and sandstone of Cretaceous age. The benchland on the east side of the plateau is cut into folded shale and sandstone of Devonian age.

Faults are conspicuous along the eastern front of the Richardson Mountains. The faults are steeply dipping and are roughly parallel to the regional trend. The remarkable scarp on the west side of the Mackenzie Delta, in the vicinity of Mount Goodenough, and the abrupt slope on the east side of the Peel Plateau between Rat River and Stony Creek are probably the result of faulting (Gabrielse, 1957).

Surficial Deposits

Surficial deposits along the Interior Route generally contain ground ice and are frequently ice rich. From the Alaska-Yukon border to just east of the drainage divide of the Richardson Mountains, the region was not glaciated so that residual colluvial and proglacial-lake deposits predominate. The bedrock is usually deeply weathered. On gentle to moderate slopes, argillite-quartzite rocks are mantled with thick silty soil and carbonate rocks with equally thick sandy silts. Granite is known to be weathered to a depth of 25 feet in one locality.

From Mileposts 297 to 330, colluvium is the most common surficial deposit encountered across pediments and rounded hills of the Old Crow Range. Deeply weathered bedrock is often exposed on the tops of ridges. Colluvium grades from mainly boulders and rock fragments on upper slopes to more silty materials downslope. Fine-grained, ice-rich silt and lake deposits occur at slope bases. The thickness of colluvium generally ranges up to 15 feet, with some of the finer downslope deposits somewhat thicker. Small lenses of ground ice are probably present in the weathered rocks of the mountains.

From Milepost 330 to 360, the Interior Route crosses the undulating Old Crow Plain, then follows the north side of the Porcupine River to Milepost 387 on the west side of the Richardson Mountains. Surficial deposits are fine grained and ice rich, with estimated thicknesses ranging from less than 15 feet to more than 100 feet. Lake deposits generally occur on the lower ground, grading upslope to rill-streaked, silt-mantled soils. Colluvium sometimes occurs on the higher slopes. Along the southern edge of Old Crow Flats, ground ice is present in large wedges and beds.

The foothills of the Richardson Mountains contain a thin cover of silt and organic silt up to several feet thick. The headwater valleys in the mountains are dominantly floored with sand, gravel, and some silt. Talus deposits flank the valley walls. Higher slopes bear a thin cover of frost-rived rubble lying over bedrock.

The Peel Plateau has been glaciated but the drift is thin and spotty, consisting of patches of silt and gravel. On the east side of the plateau is a bedrock bench with a thin veneer of alluvial silt, sand and gravel. The Peel Plateau is primarily bedrock; ground ice is probably confined to thin beds and lenses along major stream valleys and in patches of till.

In summary, approximately 12 percent (21 miles) of the route is covered by thick Quaternary deposits. About 140 miles (78 percent) would be across unglaciated terrain. Within this unglaciated area pediments are the dominant landform.

Additional information relating to the surficial materials, particularly their stability, is presented below under Mass Wasting, Erosion, and Permafrost.

Mineral Resources

Metallic and Nonmetallic Mineral Resources--Other than construction materials, no metallic or nonmetallic mineral deposits are mentioned in available source material. Sand, gravel, and rock are widely distributed along the Interior Route and, as the Applicant has selected tentative borrow sites, it may be assumed that the quantity and quality of those resources are adequate.

Oil and Gas--A detailed listing of oil and gas production and potential is provided under the description of the existing environment along the proposed route (Section 2.1.2.3).

Seismicity

The recorded earthquake history along the Interior Route is short relative to the time over which strains accumulate to produce an earthquake, hence the historic record of seismicity is a limited guide to future seismic risk. Earthquakes of magnitude 6 and larger are potentially destructive, and earthquakes of magnitude 5 may cause local damage. North of 65° N. latitude, the seismic history is probably complete since the early 1930's for earthquakes as small as magnitude 6 and since the late 1950's or early 1960's for shocks as small as 5 (Stevens and Milne, 1973; Leblanc and Wetmiller, 1974).

The two largest historic earthquakes along the route were in the magnitude range 6.25 to 6.50 and occurred in the vicinity of the Yukon-Northwest Territories boundary. The epicenters of the two earthquakes are located within about 30 miles of the Interior Route in the eastern Richardson Mountains near Fort McPherson. The accuracy of the epicentral determinations is unknown but may be no better than 60 miles (Leblanc and Wetmiller, 1974). The several maps and catalogs of historic earthquakes in the Canadian Arctic published by the Department of Energy, Mines and Resources in Ottawa, Canada (for references, see Stevens and others, 1973, appendix 2) reveal a persistent concentration of seismicity in the vicinity of the Yukon-Northwest Territories border north of 65° N. latitude. West of the Richardson Mountains to the Alaska-Yukon border the historic level of earthquake activity is low.

The earthquake potential along the Interior Route specified in terms of maximum expectable earthquakes is summarized in Table 8.1.2.9-5 (see Summary Section). The maximum expected earthquake is the largest earthquake that on the basis of existing knowledge may reasonably be expected to occur along a specified segment; it everywhere equals or exceeds the largest known historic earthquake. The zonation of the route might be further refined if more complete geologic and geophysical data were available.

Although no faults with surface expression are known to be active in this area, detailed geologic field investigations in regions of high potential seismicity might reveal evidence for geologically recent movements (Stevens and Milne, 1973). Without knowledge of the seismically active faults along and adjacent to the Interior Route, there is no basis for assigning the maximum expected earthquakes to a specific fault. Hence the occurrence of the maximum expected earthquake anywhere along the Interior Route must be considered possible.

Mass Wasting

There are three general categories of mass wasting along the Interior Route between the Alaska-Yukon border and Fort McPherson: solifluction, debris slump, and rock falls. More than 50 miles of the route cross terrain of possible moderate hazard from mass movement.

Solifluction is prevalent throughout much of the route wherever slopes are gently sloping and underlain by fine-grained materials. The solifluction mantle is widespread in the area between the Alaska-Yukon border and the Richardson Mountains. Although the solifluction features look fresh and many of the slopes display streamline features and horsetail drainage, more data will be required to determine if these slopes are active.

Isolated, small slumps of unconsolidated debris are present along the Driftwood, Porcupine, Old Crow, Bell and Peel Rivers, particularly where the river impinges against the bank (as on the outside of a meander). Melting of ice within these oversteepened slopes commonly results in slumping of blocks of frozen sediment into the river.

Within the Richardson Mountains, talus and block rubble are common on the sides and at the base of steep valleys.

Erosion

Most active erosion along the Interior Route occurs at the major river crossings such as those of the Driftwood, Old Crow, Bell and Peel Rivers. Erosion is concentrated during the peak runoff periods of late spring and early summer as the water in the channels shifts from bank to bank, widening and forming new channels and scouring the channel floors. The buildup of aufeis at certain locations along the river during the winter can produce local flooding and significant channel shifting.

Of lesser importance in terms of volume of erosive products is gullying on hill slopes. This occurs where removal of the organic mat by man, or by natural processes such as mass wasting or fire, has exposed the underlying ice-rich sediments. Upon melting of the permafrost at these localities the original small scar becomes the site of increased erosion and gullying as rain and melt water are channeled into the newly formed gully.

Erosion by water is almost non-existent during the long winter and most of the winter's total precipitation is stored until late spring and early summer. The ubiquitous permafrost underlying most of the land in this portion of Canada forms a shallow barrier to infiltration and results in increased runoff during the spring snowmelt period. Flooding, erosion and aufeis conditions are particularly prominent along the Old Crow, Porcupine, Driftwood, and Bell Rivers.

Alignment of the Interior Route is such that about 47 out of 178 miles is located parallel to and within approximately 1 mile of streams and rivers. None of the route is located in active flood plains, but about 4 miles would be located in inactive flood plains.

Permafrost

Permafrost (perennially frozen ground) forms a virtually continuous layer to a depth of several hundred feet beneath the surface of northern Canada. It tends to thin southward, and occurs in increasingly discontinuous patches near its southern limit. Even in the coldest parts of Canada, a thin "active layer," which thaws every summer, separates the permafrost from the ground surface. Its thickness can vary locally from 0.5 to 5 or more feet and can change dramatically when the surface is disturbed.

The entire Interior Route between the Yukon-Alaska border and Fort McPherson is underlain by continuous permafrost, and potential ice-rich permafrost may occur along 160 miles of the route. Across the southern edge of the Old Crow Basin, the route approaches the southern limit of continuous permafrost and the active zone is probably up to 4 feet thick. The soils here are fine grained and ice rich, and ground ice is present as large wedges and layers. Small lenses of ground ice are probably present in the weathered rocks of the Old Crow Range.

Through the Richardson Mountains, the Interior Route also lies near the southern limit of continuous permafrost. Ground ice in the form of thin discontinuous beds and lenses is extensive in the foothill area. Large masses of ground ice are present in the valley of the Bell River and its lake-strewn headwaters.

On the Peel Plateau ground ice is probably confined to thin beds and lenses along major stream valleys and in patches of till. Temperature observations in a test well on the Peel Plateau at an elevation of 1,300 feet indicate that the bottom of permafrost is 400 feet below the surface (Mackay, 1967). Alluvial ice-rich silts and sands occur on the Peel River terrace.

Soils

Soils of the Interior Route are predominantly Gelic Gleysols, Eutric and Gelic Regosols, and Lithosols.

In the Old Crow Basin, Gleysols occur between the Alaska-Yukon border and the settlement of Old Crow along the northern edge of the Old Crow Range. From Old Crow to the western foothills of the Richardson Mountains, Regosols are the main soil type, with Gleysols found along the Eagle River.

The Richardson Mountains are characterized by coarse textured Lithosols on steep mountainous slopes and finer grained, ice-rich Regosols at lower elevations.

To the east of the Richardson Mountains, Eutric Regosols are found on ice-rich morainal deposits.

Water Resources

Surface Water

The Interior Route crosses about 58 watersheds between the Yukon Territory-Alaska border and the Peel River. Six of these watersheds are larger than 100 square miles. The watershed of the Old Crow River is the largest and has about 5,520 square miles above its intersection with the Interior Route.

The magnitude and variability of winter streamflow along the Interior Route south to the Peel River is virtually unknown. Most small streams probably have no flow for most of the winter. A field party in late winter 1973 (McCart, 1974) observed water flowing under ice in Driftwood, Waters, and Bell Rivers. There was no flow observed in Old Crow River and Surprise Creek. No observations concerning flow were reported from the other streams. Maximum runoff usually is the result of snowmelt in May or early June and ice jams can produce backwater resulting in maximum water levels. Although rare, intense summer rainstorms can produce rapid rises and significant flooding. There have been no systematic hydrometric data collections on these streams; only the Porcupine River is gaged (Table 8.1.2.1-1).

Surface waters in the area crossed by the route vary in degree of mineralization and hardness depending on whether they rise in the Cordilleran or Interior Plains Regions. Streams originating in the

Table 8.1.2.1-1 Summary of selected streamflow records along the Interior Route 1/

Station no.	Name	Drainage area (sq.mi.)	Location	Discharge records	Type of gage	Operation	Mean (cfs) (in)	Max. daily (cfs)	Min. daily (cfs)	Remarks
	YUKON RIVER:									
09FB001	Porcupine R below Bell R, Y.T.	13,900	67°26'25" 137°47'01"	64-65 68-	R R	S S	-	100,000 6-1-72	-	Alternate interior route
09FD001	Porcupine R at Old Crow, Y.T.	20,900	67°33'50" 139°53'00"	61-64 65-68 69-	M M M	C S C	13,200 8.58	218,000 5-22-71	425 3-30-69 5-2-72	Alternate interior route

---

1/ Water Survey of Canada annual data reports.

Table 8.1.2.1-1 Continued

M	Manual gage.
R	Recording gage.
C	Continuous operation.
S	Seasonal operation.

NOTE: The number of years used to compute or estimate the mean discharge does not necessarily correspond to the full period of continuous gage operation shown. Means for seasonal records were estimated in a few cases. These estimates should be reasonably reliable, since winter flows were generally low.

The maximum daily discharges are shown for most stations because that was all that was published. Instantaneous discharges are shown when they are available. The maximum daily discharge may be considerably smaller than the instantaneous peak for small and intermediate streams. Maximum stages are not shown, but they may or may not have occurred at the time of maximum discharge. The highest stage might occur as the result of an ice jam.

Caution should be used in interpreting minimum-flow figures. They are the lowest values published, but lower values may have occurred during periods of seasonal observations.

Cordilleran Region contain medium-hard water of the bicarbonate type. Many of the tributaries that flow through the Interior Plains increase in hardness and sulfate content.

During the winter months when streams are frozen and the terrain is snow covered, suspended-sediment concentrations are low, generally less than 70 mg/l (Stichling, 1974). Suspended-sediment concentrations during the open-water season are quite variable. Highest concentrations occur during spring breakup and summer-storm events. Generally, average sediment concentrations are higher in the southern regions than in the northern regions.

Ground Water

The Interior Route crosses the continuous permafrost zone in the Northern Hydrogeologic Region (Figure 2.1.2.5-7). The permafrost is overlain by an active layer ranging in thickness from a few inches in the finer soils to several feet in the coarser soils.

Development of ground-water resources has not occurred in the continuous permafrost zone. The villages of Fort McPherson and Old Crow obtain their water supplies from surface water (Brandon, 1965). However, ground water probably could be obtained from the alluvium adjacent to the streams.

Ground-water quality along the route is generally unknown. In the Cordilleran Region, analyses of base flows in some of the streams indicate medium-hard water of the bicarbonate type with moderate concentrations of dissolved solids. In the Interior Plains the water increases in hardness and sulfate content.

Vegetation

Vegetation is treated here for 140 miles of right-of-way and adjacent areas in the Yukon and 38 miles in the Northwest Territories (Figures 8.1.2-1 and 8.1.2.1-1). The alignment crosses the Old Crow Range, Porcupine Plateau, and Richardson Mountains and passes into the Peel Plateau. The discussion is primarily based upon Hernandez, 1974; CAGPL, 1974e; and Environment Protection Board 1974 (vol. III). All the vegetation falls within the Tundra and Forest-Tundra Formations (Figures 8.1.2.1-2 and 3).

Tundra Formation

Alpine Tundra--Alpine tundra of the British and Richardson Mountains, in the northern Yukon Territory (Table 8.1.2.1-2), occupies the upper slopes from treeline to the limit of vegetation. Beyond the alpine communities the mountains are exposed rock deserts devoid of vegetation, or may have only a cover of lichens. Vegetation at the highest elevations consists of crevice communities primarily of mountain avens (*Dryas octopetala*, *D. integrifolia* subsp. *integrifolia*, and others) and lichens such as *Cetraria cucullata* and *Thamnolia subuliformis*. Numerous secondary species occur, including grasses, low-growing heaths, ferns and a large variety of forbs, among which saxifrages (*Saxifraga* spp.) are prominent.

Dry meadows at elevations of 1,500 to 5,000 feet, and most often at 2,000 to 4,000 feet, are common in the Yukon. These meadows include many of the same species as the crevice communities, such as mountain avens and lichens. Warmer and drier south-facing slopes have a thinner cover and a

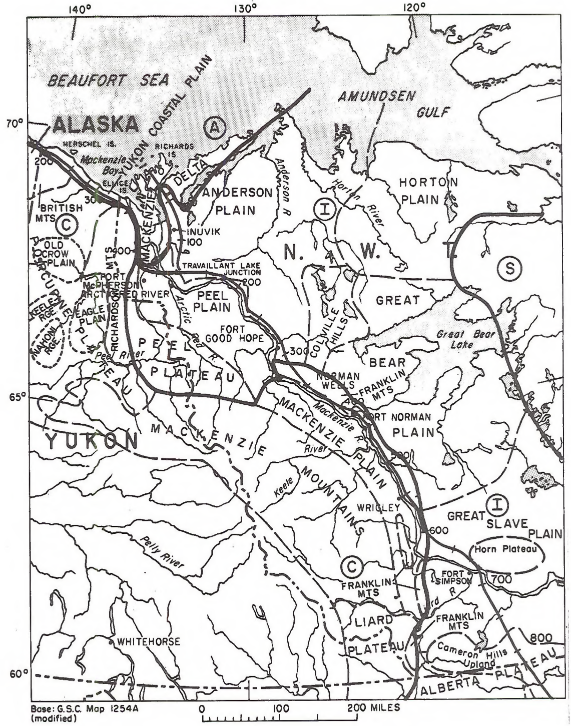


Figure 8.1.2.1-3 Selected physiographic provinces and subprovinces north of 60° N latitude

Table 8.1.2.1-2 Distribution of plant communities in the northern Yukon interior and coastal mountains 1/

	PHYSIOGRAPHIC REGION					
	INTERIOR				COASTAL MOUNTAIN	
Community Type	Peel Plateau	Richardson Mountains	Porcupine Plateau	Old Crow Range	British Mountains	Arctic Plateau
Forest-Tundra						
Mature forest-tundra	5	12	53	12	–	–
Hardwoods & mixed woods	2	–	10	–	–	–
Tall shrubs	6	4	3	–	–	–
Alpine & Low Arctic Tundra						
Low shrub-heath	17	30	2	25	23	8
Cottongrass tussock	44	3	7	15	14	21
Wet sedge meadow	6	2	–	–	–	–
Dry meadow	–	–	–	–	26	28
Other[2]	–	16	–	9	–	–

[1] Adapted from Hettinger et al. (1973). Data did not total 100% in original.

[2] Includes rock with crustose and foliose lichens in Richardson Mts. (10%) and Old Crow range (9%) and seasonal grass and herb steppe for Richardson Mts. (6%).

greater variety of forbs with showy flowers while cool, moist north-facing slopes have a more complete cover in which low shrubs are dominant. Meadow vegetation includes numerous grasses (*Arctagrostis latifolia*; *Calamagrostis canadensis*; *Hierochloe alpina*), sedges and rushes, dwarf willows (*Salix phlebophylla*; *S. glauca*; *S. reticulata*; *S. rotundifolia*) and heaths including lingonberry, cranberry, alpine azalea (*Loiseleuria procumbens*), Lapland cassiope (*Cassiope tetragona* subsp. *tetragona*) and Lapland rosebay (*Rhododendron lapponicum*). Dry-meadow communities extend to lower elevations on thin, rocky soils, talus, scree slopes and rocky ridges. At lower elevations they grade into communities typical of Herbaceous Coastal Tundra and Low Shrub-Heath Tundra.

The Interior Route enters the Yukon at an altitude of about 1,200 feet in the Forest-Tundra Formation and crosses the north edge of a small area of Alpine Tundra for about 10 miles but does not actually cross typical, continuous alpine tundra vegetation. Some pipeline facilities, however, would occur in the main body of alpine tundra communities, as will be discussed later (Table 8.1.2.1-3). The low elevation of the pipeline route brings it into Low Shrub-Heath Tundra through this region, including discontinuous alpine dry-meadow communities, depending upon site conditions. The alignment again crosses Alpine Tundra for a distance of 30 miles in the Richardson Mountains but again at elevations where Low Shrub-Heath and Herbaceous Coastal Tundra communities and mosaics of tall shrubs, white and black spruce, and birch communities are common. About 78 percent of the route lies below the upper altitudinal limit of trees.

Herbaceous Coastal Tundra--Although the Coastal Tundra is not crossed, throughout the Interior Route, similar cottongrass tussock communities are common on lower slopes, especially in the Old Crow Range and Peel Plateau (see Forest-Tundra below). Wet sedge meadow communities are nowhere extensive and have a limited, scattered distribution on low, wet sites.

Low Shrub-Heath Tundra--As previously mentioned, communities of this type are common at lower elevations throughout the regions of alpine tundra, especially in the Porcupine Plateau where they are relatively less important. See also Forest-Tundra, below.

Forest-Tundra Formation

The community types as described for the proposed route (Section 2.1.2.6) within this formation are represented in some degree and all general comments made there apply to the Interior Route.

In the Old Crow Range low shrub-heath covers 25 percent of the terrain and maintains similar coverage along the entire route except in the Porcupine Plateau (Table 8.1.2.1-2) where it is only 2 percent. Lower slopes often have a community of the cottongrass tussock type (*Eriophorum vaginatum* subsp. *vaginatum* with a closed ground cover of mosses (*Hylocomium splendens* and *Aulacomnium acutifolia*) and lichens (*Cetraria cucullata*). Tussock communities are most widespread in the Peel Plateau where they constitute 44 percent cover.

Mature forest-tundra communities reach their greatest development in the Porcupine Plateau with a cover of 53 percent. Black spruce is a dominant species throughout the route wherever trees occur and forms partially closed forests on lower, moist slopes and in wet depressions (CAGPL, 1974e). These forests have a dense understory of alpine blueberry (*Vaccinium uliginosum* subsp. *alpinum*) and lingonberry.

Table 8.1.2.1-3 Estimated areas of vegetation affected by the Interior Route, Alaska-Yukon border to Fort McPherson 1/

	Vegetation (Acres)		
	Alpine Tundra	Forest-Tundra	Total
Right-of-Way	582	2,014	2,596
Compressor Stations	43	74	117
Communication Towers	22	32	54
Airstrips	--	650	650
Permanent Project Roads	175	124	299
Temporary Access Snow Roads and Winter Trails	72	704	776
Wharves, Stockpiles, Camps and Miscellaneous Pads	68	128	196
Borrow Pits	80	220	300
Total	1,042	3,946	4,988

1/ Adapted from CAGPL, 1974, Section 14e.1.10; AAGPC, 1974, Chapter 5, and Environment Protection Board, 1974, Vol. 3.

Mature riparian forests of white spruce occur along flood plains of the Porcupine River and other streams and closed forests of white spruce also occupy terraces, abandoned flood plains, and well-drained upland slopes. These forests have an understory of alpine blueberry and shrub birch (*Betula glandulosa*) and ground cover of mosses. Stunted white spruce occurs in ravines on old slope failures (CAGPL, 1974e).

In the low wetlands of the Old Crow Flats, white spruce is well developed on ridges of old meander scars where it is mixed with willows and alders; black spruce with Labrador tea, lingonberry, shrub birch and cloudberry occurs on muskeg; and the only other tree species present, white birch, occupies lake shores.

Hardwood and mixedwood communities are displayed in many variations throughout the alternative route eastward of the Old Crow Range. Successional stages on riparian sites and on burn areas contribute to the variability. Tall shrub communities of willow (*Salix alaxensis*) and balsam poplar occur on river bars and the latter species forms closed forests on many fossil flood plain terraces. Mixedwoods of birch and white spruce associated with alder, form closed forests on well-drained slopes of the Porcupine Plateau. In the same areas moist, north-facing slopes have a community of scattered black spruce, white birch and alder with a ground cover of lingonberry, Labrador tea and mosses.

The Peel Plateau has a cover of cottongrass-tussock, low-shrub-heath and mature-forest-tundra communities. Much of the plateau is covered by a community of open black spruce and tamarack with a closed understory of Labrador tea, lingonberry and cloudberry and ground cover of sphagnum mosses. Dwarf-shrub communities, many of which are of the dry-meadow type common in the Alpine Tundra, are characteristic of the route across the Richardson Mountains. On the approach to Fort McPherson the streams draining the eastern slopes of the Richardson Mountains have mature riverbank spruce communities as does the adjacent delta.

Along the immediate right-of-way in the Forest-Tundra, from the Alaska-Yukon border through the Old Crow Flats, about 49 percent of the mileage of the route through this formation, the vegetation is predominantly of open to scattered black spruce with willow and alder or low shrub-heath ground cover; tall shrub communities along water courses; occasional closed black spruce forest, or mixtures of white and black spruce; and rare low shrub-heath communities lacking trees.

East of Old Crow Flats to the Alpine Tundra of the Richardson Mountains (about 35 percent of the total Forest-Tundra crossed), the route has vegetation cover that is about 50 percent cottongrass tussock tundra. The remainder is principally open to scattered white and black spruce forest and tall shrub communities.

From the Richardson Mountains Alpine Tundra to Fort McPherson, a distance of about 20 miles (14 percent of the Forest-Tundra traversed), cottongrass tussock tundra predominates, with some low shrub-heath communities. Tall shrubs are common along watercourses and mature riparian spruce communities occur along the Peel River and its several tributaries that are crossed.

Wildlife

Fish

There are only a few small lakes in the vicinity of the Interior Route. Most of the fish production is associated with streams.

From the Alaska-Yukon border to the Richardson Mountains, the Interior Route would cross small to medium sized streams in the Porcupine River drainage. This section of the route would follow the Porcupine River valley or the adjoining foothills much of the way; the stream gradients are slight. From the Richardson Mountains to Fort McPherson the route would cross only small streams that drain into the Peel River which subsequently empties into the Mackenzie River. The stream gradients are steep until the valley of the Peel River is reached.

Many of the larger streams tend to be turbid, especially after spring breakup. Smaller streams tend to be clear except during the spring breakup. All headwater reaches and the entire length of some of the smaller streams have coarse bottom substrates. Other small streams have silt near the mouths and most of the larger streams have silt substrates.

Only three over-wintering areas have been identified among the small streams; Fishing Branch River, Strangle Woman Creek and a site on a tributary of Pass Creek. Apparently, most fish over-winter in the mainstem Porcupine or downstream in the Yukon River.

Seasonal migrations of resident species are complex and varied. In general, there is a spring dispersal from over-wintering areas and a reverse autumn migration.

More species are normally found at a given location in the Porcupine drainage than in the Beaufort Sea drainage. However, there is only a slight difference in the total number of species reported from the two areas by various investigators (Table 2.1.2.7-1). Apparently, species that may be found at several locations within the Porcupine drainage are only rarely found in the Beaufort Sea drainage. Species reported in the Porcupine, but not the Beaufort, drainage include: three salmonids (coho, chum and chinook salmon), lake chub, Arctic lamprey, longnose sucker, and trout perch. From the literature available, the status of lake trout in the Porcupine drainage is uncertain. At any rate, it apparently is not found in the vicinity of the Interior Route. Reported in the Beaufort Sea drainage, but not in the Porcupine, are Arctic char, fourhorn sculpin and pond smelt.

The more noticeable differences between the two drainages are the greater number of species usually present in Porcupine watershed streams, the absence of char in the Porcupine, and the presence of salmon. The most common species in the Porcupine drainage are Arctic grayling, round whitefish, longnose sucker, and slimy sculpin. This is a recurrent group apparently occurring in over half of the area streams. Salmon are seasonally abundant in some streams.

Little is known about the fish populations of the streams that the portion of the Interior Route east of the Continental Divide would cross. Presumedly, they are similar to other small streams of the northern Mackenzie drainage.

A small subsistence fishery exists in the Porcupine drainage, primarily for salmon. There is a light sport fishery and no commercial fishing.

Mammals

The area along the Interior Route is habitat for a variety of mammal species (Table 2.1.2.7-9): black bear, lynx, squirrels and marten inhabit wooded areas. Mink, beaver, and muskrat are abundant in Crow Flats; otter are much less numerous. Grizzly bears frequent the general area and recent studies show that den sites that are used year after year occur in the northern Yukon segment of the Interior Route.

Wolves and foxes are common throughout the length of the route, and moose are to be found in preferred habitat, particularly on the Old Crow Flats. During spring and fall migrations moose cross the route in the Old Crow Range while moving from Old Crow Flats to the more southerly mountainous regions.

Dall Sheep are sparse throughout the region but occur occasionally in the Chute Pass area of the Richardson Mountains.

Perhaps the most economically and biologically significant mammal species present along the route is the caribou. The Porcupine caribou herd, an international herd, numbers between 93,000 and 120,000 animals and normally winters in the upper Peel and Porcupine Rivers drainages, well south of the pipeline route. However, migration movements are to be expected to cross the Interior Route throughout the entire section.

Birds

The Mackenzie Delta is one of the major waterfowl staging, nesting and molting areas in North America, and probably is the most important waterfowl production area in Canada. A very minor portion of the Interior Route passes through the extreme upper portion of this delta.

The Old Crow Flats is second only to the Mackenzie Delta as a waterfowl production area in northwestern Canada. It supports a breeding population of 75,000 to 170,000 ducks, is a major molting area for scoters, a major nesting area for canvasbacks, a nesting area for Canada and white-fronted geese and whistling swans, and the only known nesting site of the Tule white-fronted goose, which is rare and may be endangered.

The portion of the Interior Route near the Alaska-Yukon border would cross habitat thought to be characteristically prime, although nesting activity in the area is actually thought to be relatively low. However, the route would pass through the Richardson Mountains, thought to contain critical nesting habitat for peregrine falcons, gyrfalcons, and golden eagles. The peregrine falcon and the bald eagle nest along the Porcupine River.

Ecological Considerations

The major ecosystems of the Interior Route are Alpine Tundra, Forest-Tundra, lakes and rivers. The riverine systems are productive of an important fish resource; lakes which are not common along the route, except in the Porcupine River drainage, are relatively less important but equally sensitive to change.

All ecosystems must currently be considered to be in a natural state of balance as there has been little human interference beyond subsistence fishing, hunting and trapping. These activities have primarily affected the region about Old Crow and Fort McPherson.

The general characteristics and interrelationships of ecosystems are discussed in Sections 2.1.2.8 and 3.1.2.8, and the comments are applicable to this alternative route. The principal differences on the Interior Route, compared to the proposed Prudhoe Bay Supply Line, are the occurrence of mountain crossings and the Alpine Tundra Ecosystem, and the avoidance of the Herbaceous Coastal Tundra Ecosystem of the Yukon Coastal Plain and the marine ecosystem of the Beaufort Sea.

Subsystems of the Forest-Tundra Ecosystem dominate the Interior Route in a complex array of plant communities and their associated animal populations mentioned in the preceding paragraphs. Within the Forest-Tundra, the Old Crow Flats constitute an ecosystem of very high productivity which includes numerous large game mammals, such as caribou, moose and grizzly bear; fur bearers, such as beaver, muskrat and mink; and large bird populations which make it one of the most highly productive areas in Canada for migratory waterfowl.

Vulnerable and possibly endangered bird species include the Tule white-fronted goose, peregrine falcon and bald eagle. The Forest-Tundra is the wintering area of the Porcupine caribou herd and the Interior Route lies across the path of its spring migration to the tundra calving and summer feeding grounds.

The Alpine Tundra Ecosystem includes a limited occurrence and distribution of Dall sheep in the Richardson Mountains. In both alpine habitats and the higher elevations of the Forest-Tundra there are critical nesting areas of peregrine falcons, gyrfalcons and golden eagles.

Economic Factors

The economic conditions relative to the Interior Route between the Alaska-Yukon Territory border and Fort McPherson, where it joins the proposed route, would be essentially the same as the conditions given for the proposed route. The only significant difference is that this route would pass within about 15 miles of the community of Old Crow, whereas the proposed route would pass approximately 10 miles from Aklavik. Old Crow and Aklavik are about 140 miles apart, and have some differences that may be worthy of consideration.

Aklavik in 1973 had an estimated population of 733, and the proximity to Inuvik has encouraged a mobile labor force accustomed to wage employment. The surrounding country has been a rich hunting, trapping and fishing area. Aklavik is supplied by river from Hay River and Norman Wells and by scheduled air service. The total income from all sources in 1973 was estimated at $690,000 or $941 per capita. Employment is chiefly in government, and oil and gas exploration, with a small private sector; 19 people are employed by the Aklavik Fur Garment Cooperative. The trend is toward part-time supplemental and recreational hunting and trapping rather than full-time reliance on the land. Only two to four people are considered full-time hunters and trappers; however, during the muskrat season nearly 70 percent of the male labor force does some trapping.

Aklavik's major development problem is the townsite location on a riverbank that is eroding 5 to 7 feet annually. The residents have resisted relocation to Inuvik, and the established private business sector includes two stores, a small hotel and cafe, a theater, the fur garment cooperative, a bakery, seven construction and contracting businesses, and service by a fly-in bank.

Aklavik was scheduled to obtain hamlet status in January 1974, and, as the community has demonstrated the ability to complete various local projects, it is assumed that with the increased local authority the plans for more economic improvements will be carried out. Thus, in the absence of the pipeline, a good rate of economic progress, similar to that in recent years, would be expected provided that the regional economy remains stable.

Old Crow had an estimated population of 216 in 1973. It has a history of good trapping, hunting and fishing, but currently has only two full-time trappers and is a wage-employment oriented community. Since the mid 1960's, oil and gas exploration activities have provided the only viable economic base. Old Crow is supplied chiefly by air from Whitehorse or Inuvik, and only bulk oil is now brought in by barge from Dawson via the Yukon and the Porcupine Rivers.

The trend toward wage employment in Old Crow does not necessarily reflect the long-term job opportunities available, as the total estimated payroll from within the settlement in 1973 was $140,000, largely from jobs in the nursing station, Native band office, school, R.C.M.P. (police), coop and post office. The residents rely heavily on caribou and fish harvests for food. Many of the young people tend to withdraw from the land-based economy and migrate to Inuvik and Whitehorse to obtain jobs.

The economic trend in Old Crow in the absence of the pipeline is difficult to assess because of the conflicting attitudes and actions of the residents. In the opinion of one analyst, the potential income that would accrue to residents from the harvest of caribou and furs over a 20-year period could exceed the projected income from proposed pipeline operations and geophysical explorations combined. Nevertheless, the residents have demonstrated a withdrawal from the traditional land-based economy. Petroleum exploration might be curtailed during the next 20 years, if a favorable potential is not indicated, regardless of pipeline construction.

Sociological Factors

The sociological conditions related to the Interior Route would be similar to those given for the proposed route. However, significant differences exist between conditions in Aklavik and Old Crow.

Aklavik's estimated population in 1973 of 733 was divided between 561 Natives and 172 classed as "others." The 1971 population was 660, of which about 295 were of working age (15 to 64 years). Among the Native group, Eskimos outnumber Indians by slightly more than 2:1. The local hamlet government is actively assuming responsibility for community improvement projects, such as housing, a food storage locker, swimming pool, indoor skating rink, employment office, and a riverbank erosion control program. In 1973 most non-government residents were housed in 97 low-rental homes and 15 people owned their own houses; more housing will be required. Water is piped to some buildings and to distribution points throughout the community, and is partially chlorinated and filtered. Sewage, refuse and trash are collected and trucked to dumping grounds. The general trend in Aklavik appears to be toward a moderate increase in population and a continuing program of up-grading facilities related to social conditions.

Old Crow's estimated population in 1973 of 216 is unchanged from 1971, owing to out-migration, and is divided between 183 registered Indians and 33 others. The working-age group in 1971 was estimated to be 103. The Native band council, which elects a chief, is the dominant political unit, and has strong control over community affairs, exploration, and related activities within the Old Crow area. The council expects any activity in the region to be approved or rejected by the council regardless of its legal rights to such power. Houses are built of logs, and the Native families own their own homes. Community services are minimal: people haul their own water and dispose of their own sewage and refuse. A school, nursing station and R.C.M.P. station are provided. The current sociological situation in Old Crow shows evidence of stagnation and uncertainty about a means of livelihood. The council is taking a hand in some civic improvements and in curbing alcohol abuse. The older people are concerned about current changes and the younger people are more disposed toward controlled development. The apparent attitude is to retain the land area in its present state but to obtain most income from other sources.

Land Use

The area traversed by the Interior Route is quasiwilderness, possessing no roads, but with a small settlement at Old Crow near the Yukon-Alaska boundary. The route approximately bisects the Canadian part of the range of the Porcupine caribou herd. Part of the area supports some spruce timber, but most vegetation is low and shrubby. The only local economic base is subsistence hunting, fishing, and trapping.

Paleontological, Archeological, and Historic Sites

A number of archeological and historic sites along the Interior alternative pipeline route in Canada have been investigated (Millar, 1974) including:

Old Crow River flood plain and stream cut,

Old Crow Lake Basin,

Klokut (prehistoric Athabaskan village), La Pierre House on Bell River (historic trading post), and

Whirl Lake

A proposal for archeological salvage along the Interior Route in Canada (Millar, 1974) lists a total of 33 sites to be examined. One of the proposed sites is classified as high priority, indicating a high probability that the site actually exists and that a survey will locate it. Seventeen sites are classified as medium priority and fifteen are low priority.

The earliest evidence of man in the New World, according to many, dates from 27,000 years ago. This evidence, a caribou tibia flesher, was found near Old Crow and probably represents some of the earliest migrants from the Old World who traveled south through ice-free corridors in the intermontane region of Alaska (Irving and Harington, 1973) As the glaciers receded and grasslands spread into the North, animals and man invaded the northern interior. The people of this time utilized a blade technology. About 8,000 years ago, forests spread into the north. Tools dating from this period reflect a life-style based on hunting, fishing and woodworking. About 4,000 years ago, ancestors of the Eskimos occupied this area. At various times since then, the boundary between Eskimo and Indian has fluctuated across the region.

Recreation and Esthetic Resources

The Interior Route would enter Yukon Territory from Alaska about 40 miles northwest of Old Crow. Near the border, the terrain is rolling, with frequent mountain streams. The route would skirt the southern edge of the Old Crow Flats, with the irregular topography of the Old Crow Range to the south. Much of the landscape here is mottled taiga and tundra over rolling hills. Eastward, the route would pass through the Richardson Mountains, which reach elevations of about 4,000 feet in this vicinity. Descending the east flank of the Richardsons, the Peel Plateau is encountered next. The route would traverse this flat, treeless plain with its deeply incised drainages, then cross flat, poorly drained terrain and the Peel River before reaching a junction with the proposed route. The variety of landforms and habitats provides a pleasant landscape and a variety of wildlife species appreciated by both hunter and observer.

While there are no official recreation areas or facilities along the route, there are natural areas and features of potential value for recreation in the vicinity. Such outdoor recreational activities as sightseeing and photography, hunting, fishing, float tripping and canoeing, hiking and backpacking could be enjoyed. The Porcupine caribou herd is potentially an important recreational resource as a unique wildlife spectacle. The Porcupine River is important for domestic fishing and potentially could be used for sport fishing. The Bell River, with its readily accessible headwaters at Summit Lake, has great potential as a canoeing river. Moreover, it joins the Porcupine River and together the two rivers are ideal for long canoe trips.

Air Quality

The only sources of man-caused pollution in the region are those associated with traffic on the Dempster Highway and the Porcupine River and with normal activities at the settlement of Old Crow (1973 population estimated at 216). Pollution consists mainly of an unknown amount of exhaust emissions from internal combustion engines on boats and vehicles and those used to power electrical generators. Home cooking and heating stoves provide a small additional increment.

Environmental Noise

Noise emissions along the Interior Route would be similar in nature and magnitude to those along the proposed route (Section 3.1.2.15).

The differences in the noise impacts along this route and the proposed route will be a function of the differences in the numbers of wildlife and people exposed to noise along the two routes. This information is provided in Section 8.1.2.1, Evaluations of Environmental Impacts: Wildlife and Sociological Factors. A comparative summary of the wildlife sensitivity for the proposed route and the Interior Route is provided in Table 8.1.2.1-4.

Since the Interior Route avoids caribou calving and post calving aggregation areas, there will be no impact on these activities from noise emissions of pipeline inspection flights (AAGPC, 1975a). This route will expose caribou to construction noise, as it crosses their winter ranges in the Richardson Mountains and the Central Yukon (AAGPC, 1975a). Noise from compressor stations located in confined areas may interfere with migratory movements (AAGPC, 1975a and McCourt et al., 1974).

Evaluation of the Environmental Impacts

Climate

The discussion of possible impacts on climate along the proposed route (Section 3.1.2.1) generally is applicable to possible impacts along the Interior Route. Local ice fog, the only impact, would not be deleterious to the climate.

Impact of the climate on the project would be similar to that of the proposed route with reference to personnel, materials and equipment. Flying operations would be hazardous due to the mountainous terrain. Cloudiness over the mountains and valleys, and accumulations of summer warm fog and winter ice fog would seriously affect visibility for both air and ground operations.

Strong down-slope and down-valley winds would add an additional element of hazard to flying operations, particularly for helicopters.

Topography

A discussion of the impacts on topography is included in the following section under Geology.

Geology

Because of the lack of precedent for a project of this type and magnitude in an arctic and subarctic environment, judgments about impacts on geology have to be based on extrapolation from past experience, test data, and current understanding of the factors that can have a significant effect on the geologic environment. The factors which separate the proposed pipeline project from other gas pipeline projects in lower latitudes are the presence of permafrost, abundance of ice-rich sediments in the terrain along the route and the transmission of gas at temperatures below freezing. Problems could arise from the degradation of permafrost caused by disturbance of the terrain and from permafrost aggradation caused by operation of the chilled gas pipeline. Consequences of these processes could affect the stability of the terrain and the integrity of the pipeline.

A portion of the material presented in this section is taken from volume IV (Research Reports) of the Environment Protection Board (1974), as well as data submitted by Canadian Arctic Gas Pipeline Limited to Canadian governmental agencies.

Disturbances Caused by Construction and Maintenance of the Proposed Pipeline System

Access facilities for the Interior Route include permanent airstrips near Mileposts 302, 348, and 397, a heliport near Milepost 433, and helipads at all communication and valve sites. Throughout the mountainous area of the Richardson Mountains, generally between Mileposts 425 and 450, summer construction roads and some all-weather roads would be developed. Some 20 miles of permanent all-weather access road (15 near Milepost 448 and 5 near Milepost 475) would be constructed to connect the pipeline route to the Dempster Highway. Winter roads would connect the Dempster Highway with the route at Old Crow near Milepost 335, and Lapierre House near Milepost 410. Additional temporary winter roads would be constructed along most of the right-of-way.

In order that construction of the pipeline over areas of muskeg, high-ice-content silts, and tundra would not cause excessive terrain degradation, the Applicant intends to utilize winter construction when the active layer is frozen and a solid footing is available for machines. Proper use of winter roads is expected to produce minimal environmental impact.

A substantial part of maintaining a pipeline and its right-of-way is surveillance and repair of critical areas which are susceptible to soil erosion. Along the route this susceptibility would occur almost exclusively in seasons when the ground was unfrozen and could be expected at locations where the pipeline would traverse steeply descending grades or the banks of streams.

The Interior Route would, in many cases, require crossing over watershed divides, and the variation in relief would result in the pipeline ascending and descending steep slopes. Ditch plugs at regular intervals in conjunction with other drainage and erosion control measures would be necessary to stem the flow of water within the pipeline ditch and avoid potential displacement of the pipe.

Operating the pipeline system would depend on the use of aircraft to transport personnel from operating bases to places requiring service or maintenance. The loss of aircraft availability because of bad weather would require either postponing maintenance and repair or resorting to surface travel along the right-of-way. Intermediate communications sites which would normally be serviced by helicopter would present particular difficulties because they would be located on high points. In the absence of helicopter-use weather, mountain climbing approaches would have to be made.

In summary, alteration of the surface during construction along the Interior Route could cause rapid degradation of permafrost with high ice content at selected locations. If it should occur, it would probably be most extensive in the Old Crow Basin between the Old Crow River and the Richardson Mountains.

In addition, rockfalls in the Richardson Mountains could be triggered by blasting. Scars from the rockfalls and slides would be of long duration but would not be unique in the landscape.

Use of Construction Material and Resulting Terrain Scars

Thirteen potential borrow and quarry sites have been designated along the Interior Route. Some of these would be outside of the pipeline construction zone.

The material source areas can be divided into four categories: (1) upland sand and gravel sources which include glacial moraines, ice-contact deposits, abandoned outwash channels, and terrace sediments; (2) river bars of braided streams which include streams commonly carrying a heavy bedload of sand and gravel; (3) inactive and active flood plains including all streams in which flow is restricted to well-defined stable channels bordering flood plains; and (4) quarry sites located on bedrock outcrops or where bedrock is within a few feet of the surface. Quarry sites would generally be on ridge or hill tops.

Estimates of the construction material requirements made by the Applicant are 4.6 million cubic yards. This includes estimated requirements for compressor station pads, measurement station pads, airstrips and helipads, all-weather roads, communication towers, stockpile sites and camp sites, but does not include the small quantities required for concrete aggregate or anticipated select backfill required locally in the pipeline ditch.

The major impact of using the natural construction materials along the Interior Route would be the expenditure of an essentially irreplaceable natural resource. There would also be many changes in the local environment caused by the excavation, transportation, and redistribution of these materials.

Devegetation and removal of the organic mat could increase the depth of the active layer and initiate thawing of the permafrost. Excavation of upland gravel sources and alluvial fans would thaw areas underlain by permafrost, alter local drainage, and increase erosion locally. Quarry sites would leave scars along ridge crests and hilltops and would require erosion control practices to prevent further degradation of the area. Soil flows, soil slumps, and landslides could develop if quarry and borrow site slopes were not left in stable or thaw-stable condition.

Stream-flow patterns would be altered by the excavation of material from gravel bars and flood plains, and pools would be created in the streams. Some siltation would also occur due to excavation in or near streams. Careful selection and proper development of the borrow pits and quarry sites could minimize all of these effects.

Some of the borrow pits and quarries would need to remain open because of an intermittent requirement for material for maintenance purposes.

Disruption of Surface and Subsurface Drainage

In some areas crossed by the Interior Route, disruption of ground- and surface-water flow could lead to ground and river icings during the winter. River icings, occurring under natural conditions, are common along the major rivers crossed by the route. Ground icings, a phenomenon encountered relatively rarely under natural conditions, is the predominant icing type in areas where conditions have been disturbed by man. The occurrence of ground icing on roads and other disturbed areas is the result of the disruption of ground-water flow by deeper seasonal freezing in the shallow water-bearing layer. Disruption of ground-water flow in the deeper water-bearing layer is presently unknown, mainly because man's activities have induced seasonal freezing only to shallow depths.

Assessing the potential of the project to cause drainage disruption is difficult for the following reasons:

1) Techniques for predicting the occurrence and severity of man-induced icings have not been developed. Predictions of icing occurrence are now based predominantly on the understanding of the natural causes and patterns of icing development.

2) Very little data on ground-water occurrence and movement are available in the region of the pipeline route.

3) There is no prior experience for a pipeline freezing the ground around it. The depth of the freezing front resulting from the operation of the chilled pipeline would increase with time up to a point; therefore the effect of the disruption of ground-water movement at greater depths would be likely to be time dependent. The time dependency, together with the lack of data, makes it virtually impossible to locate the specific areas of potential impact.

The likely impact of the proposed project is examined in the following paragraphs in terms of components such as roads, airstrips, river crossings, and right-of-way of the chilled pipeline. The effects of drainage disruption on terrain, structures, and related activities is the predominant impact considered.

Roads and Airstrips--Roads and airstrips, especially where built along sloping terrain, could cause drainage disruption by initiating ground icing. However, where the major length of each permanent road would be parallel to the drainage, only short segments would be potentially subjected to ground icings; where these were identified after the construction, counteracting measures could be taken.

Areas kept clear of snow, such as highways and airstrips, would experience greater seasonal frost depths. Where this deeper frost line merges with an impermeable layer such as the underlying permafrost, water might be forced to the surface to create the icing.

River Crossings--The presence of a chilled pipeline buried in the riverbed could reduce the cross-sectional area available for flow in the alluvium. Such a reduction would continue as the frost bulb increased. This would provide conditions favorable for the formation of river icings.

Under natural conditions, usually not all of the stream water emerges in the form of icings; a portion flows along the channel and in the riverbed. However, the presence of a frozen core caused by the chilled pipeline at river crossings would intensify river icing activity. Many streams and rivers that presently flow throughout the winter could, as a result, freeze to the bottom. Freezing of the riverbed might be local if a significant portion of the winter flow were derived from springs downstream of the crossing; but if the springs providing the winter flow were upstream of the crossing, much of the downstream reach could be completely frozen.

River icings can be viewed in terms of their effects on nearby engineering structures or their effects on the river regime and the biotic environment. It would seem possible to locate structures such as compressor stations to reduce or eliminate potential problems from icings through detailed site investigations.

River icings could be so severe that they might invade nearby compressor stations, particularly those on flood plains. The icing would raise the level of the river channel with the result that flood stages might be considerably higher than previously.

Pipeline Right-of-Way--The presence of a chilled gas pipeline in areas with permafrost would lead to effects different from those in areas with no permafrost.

In areas with permafrost, a chilled pipeline could reduce the depth of the active layer above the pipeline axis relative to areas away from the pipeline. The reduced active layer thickness could act as a dam or weir producing ponding on level ground and redirection of drainage on sloping terrain. Ponding could lead to thermokarst subsidence and redirection of drainage could lead to slope instability at the point of discharge. In winter, ground icings could be formed along large sections of the pipeline by surfacing of the ground water trapped between the freezing front and the permafrost table.

In areas with no permafrost, the chilled pipeline could form a frozen core. This core might extend to greater depths with time and intersect water-bearing layers. Areas normally recharged by these layers would dry out.

Earthquakes and Active Faults

Large earthquakes, if they were to occur, could be serious hazards to the integrity of a pipeline along the Interior Route. Seismic shaking or surface faulting accompanying a large shock could rupture the pipeline directly or cause failure in the foundation material that could lead to rupture. Furthermore, large earthquakes could trigger landslides that could break the pipeline. From Prudhoe Bay to the Richardson Mountains, low seismicity characterizes the area. The Interior Route crosses the Richardson Mountains seismic zone west of Fort McPherson, where earthquakes of up to magnitude 6.5 have been recorded within a few miles of the route. Although the strike-slip fault system along the east side of the Richardson Mountains is apparently associated with earthquakes, there are no surface indications of recent movement.

Permafrost Thawing and Frost Heave

Pipeline rupture could result from slope failures caused by degradation of permafrost, redirected surface and ground water, and differential movement caused by frost heaving. Terrain instability such as thermokarst subsidence, gullying and slumping could result from damage or removal of the insulating peat layer during construction, operation, and maintenance of the pipeline.

The potential impact of the pipeline project on permafrost terrain can be examined in terms of several of the processes generated. The processes considered here are permafrost degradation and permafrost aggradation (frost heave). One of the major concerns is the effect that the gas pipeline and related structures and activities could have on permafrost terrain. In areas with high ice-content soils, disturbances that damaged or removed the peat layer could lead to permafrost degradation. When this happens thermokarst subsidence, gullying, solifluction, and slumping could occur. The effects are of lesser magnitude in areas with low ice-content soils.

Factors Affecting Terrain Reaction--It has been generally observed that the levels of terrain reaction to disturbance depend on the properties of the terrain, the season, the intensity of disturbance, and the time elapsed.

Terrain sensitivity, a measure of the possible reaction to disturbance, is governed by properties such as vegetation, peat thickness, ice content, and slope.

Vegetation has a direct influence on the amount of heat entering and leaving the ground. Reducing the living vegetation, all other things being equal, leads to an increase in thickness of the active layer (Linell, 1973).

Compression of the peat layers reduces insulating properties, and in areas of high ice-content soils, thermokarst subsidence may ensue. Removal of the peat layer exposes the soil surface to greatly increased heat flux; thermokarst subsidence, gullying, or slumping may result.

On level terrain, surface instabilities are predominantly manifested as thermokarst subsidence and ponding. On sloping terrain gullying and slumping, which may increase with time, develop from disturbances.

The time of year when the disturbance occurs is a critical factor in determining the depth of disturbance of the peat layer and the ensuing reaction of the terrain. Because frozen ground is normally much less vulnerable to damage than unfrozen ground, the same amount of disturbance will produce a lower level response on frozen ground than on unfrozen ground. Observations of past disturbances have shown that summer operations cause the most damage, typically in the form of rutting, thermokarst subsidence, slumping, and gullying. In summer, even one pass of a vehicle may result in permafrost degradation and ground subsidence.

Activities related to the construction, operation, and maintenance of a pipeline along the Interior Route would involve the movement of men and equipment in varying intensities and at varying times. The traffic could range from a few passes of men on foot to frequent travel by heavy vehicles. Such activity in summer could progressively lead to reduction in the vegetative cover, compression of the peat, and ultimately, to damage and removal of the peat layer. The consequence could be severe thermokarst subsidence and slumping.

Time Since Initial Disturbance--Uncertainties still exist concerning the reaction of terrain over a period of many years to disturbances that compress the peat layer. Moderate compaction of the peat layer may lead to thermokarst subsidence that appears only after several years (Haugen and Brown, 1971).

The activities related to the project that have the potential for causing permafrost degradation are: clearing, grading, burning slash, construction traffic and traffic for maintenance and emergency repairs. Some or all of these activities are pertinent to project facilities including borrow pits, roads, airstrips, compressor stations, communication sites, and the pipeline right-of-way.

Surface traffic for emergency repairs and unscheduled maintenance in the thaw season would result in a high level of disturbance of the surface. In summer, even one pass of a light-pressure vehicle would compress the organic layer and lead to thaw. Although the immediate effect would only take the form of a depressed surface with ponding, the effect over a period of years is more difficult to predict and would depend on the amount of compression of the peat layer, the ice-content profile, and the climate. Moderate to severe compression of the peat layer could conceivably lead to slumping and gullying.

Frost Heave and Heaving Pressure--The commonly known aspects of frost heave are the heave and heaving pressure that arise from seasonal freezing of the ground and can act on pavements and foundations. Seasonal freezing of the ground generally lasts less than 6 months and affects depths of less than 10 feet. The chilled pipeline, on the other hand, would produce a condition of continuous freezing that would last 30 years or more and affect the ground to a depth of about 30 feet. This long continued deep freezing of the ground could lead to a substantial buildup of heave and heaving pressures that could endanger the pipeline.

The advance of the freezing front into the ground would result in ground heaving and, possibly, differential heave of the pipe. Ground heaving would increase with time and could lead to subtle changes in surface drainage patterns along the route. The changes could affect the nearby vegetation. Potential differential heaving of the pipeline is a major concern because it could possibly damage the pipeline. The different surficial geologic units, including the different soils within each unit, together with the different water conditions along the route would certainly lead to differential heaving.

Assessing the potential of the chilled pipeline to cause heave is difficult because: 1) there are presently no comprehensive theories that predict the heave and heaving pressure likely to be generated; 2) the location of the ground-water table in the discontinuous permafrost zone is presently unknown along the major portion of the route. Further, the Applicant has not demonstrated that a buried, chilled pipeline can be operated safely in the permafrost region, especially in the discontinuous permafrost zone.

Instability of Slopes Including Cut Slopes

The various forms of mass movement of soil, whether occurring as a natural process or as a result of construction activity, can be broadly grouped into 1) shallow failures generally parallel to the slope, and 2) deep-seated failures.

One effect of construction disturbance is to increase the depth of thaw. Thawing usually diminishes soil strength in degree depending upon soil type, nature and distribution of ground ice, and the rate of thaw. An unfavorable combination of circumstances may result in a shallow failure.

For a buried pipeline, shallow failures on the right-of-way or in the ditch backfill above the pipe might not directly threaten the pipeline. A shallow failure on the right-of-way, however, might start surface water erosion which ultimately could affect pipe stability.

A deep-seated failure would present great threats to the pipeline. A failure involving soil movement to a depth greater than 8 to 10 feet would be considered deep-seated. Such a slope failure would be most likely to occur along riverbanks. Steep slopes adjacent to the route within the Richardson Mountains might also be susceptible to deep-seated failures due to deep thawing of permafrost.

Some forms of movement associated with thawing soils result from natural processes and not disturbances by man. These include: solifluction, creep in the thawed active zone, large-scale slumping, small-scale slumping such as that found in ice-wedge polygon terrain, and retrogressive failures.

The process of slow, gravitational, downslope movements of saturated, non-frozen soil behaving as a viscous mass over a surface of frozen material is a naturally occurring process and is commonly called solifluction. Areas of intense solifluction should be avoided by appropriate route location. Where significant solifluction is anticipated, extra depth of cover should be provided so that the pipe will be buried in stable ground. Slow solifluction movements would probably not affect the integrity of the pipe.

Cut slopes would present special problems of slope failure. Cut grading would expose the mineral soil to thaw, and in level terrain, thermokarst subsidence and slumping could be anticipated. In terrain with a grade of 5 percent or more, gullies could be formed and reach depths of 3 feet at the end of one summer, increasing to about 10 feet with time in areas of ice-rich soils. Cut grading would probably be required at approaches to river crossings along the route. Thaw of the high ice-content soil would produce thermokarst subsidence, slumping, and gullying and would lead to increased siltation of the river. In this region, all water courses--regardless of size--are potential sources of instability if disturbed.

Rockfalls in the mountain regions could be triggered by blasting.

Accelerated Erosion

Erosion, as discussed in this section, refers only to accelerated erosion caused by man-made removal or disturbance of surface vegetation and soil. Once initiated, the rills and gullies that rapidly form can be very difficult to control. Such erosion in the pipeline right-of-way and its vicinity would be undesirable and would be detrimental to revegetation and restoration measures.

The principal factors governing the rate and severity of erosion due to the action of water are vegetation at ground surface; upslope topography, and in particular the steepness and length of slope; location of the right-of-way relative to the watershed; rainfall intensity and duration; infiltration rate of the soil; sediment load of surface runoff; and texture, structure and chemistry of the soil in the top 6 inches below ground surface.

Surface erosion during spring runoff would be low, as the ground is usually frozen and the bonding at ground surface prevents soil particle dislodgement. Maximum erosion would occur during the summer storm runoff. The potential for erosion would be greatest where the soil in the backfill mound and disturbed places on the right-of-way would be exposed to flowing water. Drainage and erosion control measures should be incorporated into pipeline construction procedures to minimize and prevent detrimental erosion. This includes the movement of both surface and subsurface water across the right-of-way and into stable drainage courses on the downslope side of the proposed pipeline.

Siltation of Streams

Siltation has the greatest potential of developing in the streams along the route where gravel extraction from flood plain deposits would occur. These localities include borrow sites within the drainages of Surprise, Schaeffer, and Berry Creeks, the Driftwood and Waters Rivers and a tributary to the Rat River.

Disruption of the river and stream beds at pipeline crossings by either forming obstructions to water flow or causing depressions in the drainage profile could lead to siltation.

Impact on Present and Future Mineral Resource Exploration and Production

The level of mineral resource exploration along the Interior Route would not be expected to increase much over the small amount of prospecting that is currently taking place. The lack of a good continuous all-weather road along the route would limit mineral prospecting. Although new airfields would undoubtedly provide access to some areas, the paucity of known or expected mineral resources along the route would discourage most prospectors.

Metallic and Nonmetallic Mineral Resources--The only impact on metallic or nonmetallic mineral resources that the construction of a pipeline following the Interior Route would have would be the consumptive use of construction materials. Probably very little of this material would be recoverable at the end of the life of the proposed project.

Oil and Gas--The gas pipeline across the Old Crow Flats that would result if the Interior Route were adopted would encourage the exploration for oil and gas in the Old Crow basin. The few possible small- to moderate-sized gas accumulations in the basin (Table 2.1.2.3-1), could be developed. Resources that might be discovered in the western part of the Mackenzie Delta would not adjoin a through-going transmission system.

Soils

Trenching and other pipeline construction activities will impact fragile topsoils along the Interior Route to a variable degree ranging from complete destruction to partial burial by addition of thin layers of excavated subsoils and soil parent material. In addition, there would be extensive mixing of topsoils with low-nutrient subsoils and parent material from the pipeline trench. Because most subsoil and underlying geologic materials that are likely to be excavated generally are not well-suited for plant growth, revegetation measures may have to be repeated several times before successful plant growth and ground stabilization can be obtained.

In permafrost areas disturbance of some soils during construction might, in conjunction with differential thawing of permafrost, cause a decrease in terrain stability and a ponding and channeling of surface waters.

The Interior Route would not cross agricultural lands and therefore there would be little impact of agricultural significance.

Water Resources

The Interior Route is 178 miles long from the Alaska-Yukon border to its junction with the proposed route at Fort McPherson, and it crosses 58 stream channels on the Peel Plateau and the Old Crow Flats. The degree of potential impact will depend upon the design and the measures taken during construction to minimize the impact. Four areas of concern are: (1) channel erosion, (2) icings, (3) depletion of streamflow during construction, and (4) drainage disruption (see table 3.1.2.5-1 for a general summary of impact mechanisms, and possible consequences).

The primary impact on ground water by a pipeline along the Interior Route would be the disturbance of the shallow active zone overlying permafrost during pipeline construction and operation (see Figure 3.1.2.5-1b). Disturbance of the thermal regime in the shallow active layer will create new ground-water flow patterns resulting in aufeis, accelerated thermal degradation, accelerated erosion, frost heaving, and possible explosive icing mounds. Another potential for impact on ground water will be the discharge of liquid wastes and leaching of sanitary landfills.

Vegetation

The Interior Route would differ from the proposed route principally in its avoidance of the narrow Yukon Coastal Plain Tundra and its crossing of mountainous terrain including Alpine Tundra vegetation types (Figure 8.1.2.1-2). The right-of-way and other facilities would utilize about 1,042 acres of Alpine Tundra lands along the Interior Route (Table 8.1.2.1-3), but only minor amounts of typical, continuous plant communities of the dry-meadow type would be crossed or affected in a significant way. Seventy-eight percent of the Interior Route to Fort McPherson crosses Forest-Tundra and the 22 percent of the right-of-way crossing the Alpine Tundra is at lower elevations than those at which true alpine plant communities occur, except in scattered distribution on drier sites of rock and thin soils. Over the entire 178 miles of the right-of-way the vegetation encountered is typical of tundra and forest communities of the Forest-Tundra Formation.

The principal effects on vegetation would be removal or disruption of communities on all lands used for the right-of-way, construction sites or borrow pits; misuse of winter roads; disruptions to drainage; clearing and erosion at river crossings; uncontrolled erosion on slopes; fire; and general impingement upon wilderness and proposed ecological reserves.

Pipeline Right-of-Way

The 120-foot-wide right-of-way, 178 miles long, would be equally divided into a snow or ice road as a traffic lane; a working lane for construction machinery; and a lane for the 8-foot-wide, 7-foot-deep pipeline trench and spoil pile. In forested areas, principally along slopes of major drainages on the east side of the Richardson Mountains, the Old Crow Flats, and along the Porcupine River, machine clearing would be practiced. Hand clearing would be used where necessary. Some degree of clearing would be required on about 60 percent of the right-of-way. Cottongrass-tussock and low shrub-heath, and sedge-grass communities which occupy about 40 percent of the route would not require any clearing. The entire 2,596 acres of right-of-way (Table 8.1.2.1-3) would be kept free of trees for the duration of the project.

The shorter term impact of the project on the right-of-way would be the destruction of an estimated 1,865 acres of vegetation on the ditch line and associated spoil mound and the temporary disruption of plant communities on the traffic and working lanes. The degree of disruption would depend upon the amount of grading that would be required and the success of snow roads in protecting the vegetation and the integrity of the moss-peat insulating mat. In the shorter term the worst case would entail total but temporary loss of vegetation from one-third of the right-of-way and moderate damage to the remainder. No long-term impact is predicted for the right-of-way but in the short term of pipeline operation, it would be removed from forest production. The overall impact of right-of-way activities would be only minor to moderate in terms of the vegetation resources of the regions traversed.

Winter Roads

Extensive use would be made of processed snow, ice-capped snow, or ice roads along the right-of-way and as access to stockpile sites and borrow pits. Availability of snow could be a major problem in road construction. The impact of snow roads cannot be predicted with confidence for slopes of mountainous terrain and the probability is high that damage to the moss-peat layer, and thermokarst erosion resulting from changed thermal regimes consequent to this peat compression or destruction, would cause moderate localized change in vegetation. An estimated 194 miles of temporary access snow roads and winter trails would be utilized. The large mileage of such roads results from the requirement for a 120-mile snow road from the

Dempster Highway to Old Crow and a 50-mile road from the Dempster Highway to Milepost 417. In the shorter term significant damage to vegetation could result from misuse of snow roads on about 776 acres, in addition to the right-of-way, but it is predicted the damage would be moderate and would have no short-term impact of significance. Snow road tests at Inuvik (see Section 3.1.2.6), which should be applicable to the Interior Route, induced little damage to ground cover vegetation or the moss-peat layer. The tests were inadequate, however, to assess the probable impact of heavy traffic loadings on side slopes.

Drainage Disruption

Vegetation might be affected seriously by pipeline interference with natural drainage patterns. Mountain crossings, either across drainages or parallel to valleys with heavy, seasonal, side-slope runoff, would be certain to alter runoff patterns. The effects on vegetation would be destruction of terrain by erosion, by drowning as a consequence of ponding upslope of the pipeline, or by vegetation being deprived of water supply in wetlands downslope of the right-of-way.

For about 40 miles through the Richardson Mountains the pipeline would lie along slopes draining to the Porcupine, Bell, Eagle, and Rat Rivers. In this area there is a threat of drainage disruption and disruption of vegetation patterns. The impact could be major in the shorter term, but, even in worst, site-specific cases, would probably be minor in the short term. The potential impact of drainage changes on the vegetation resources of the region in an overall sense is predicted to be minor.

Stream Crossings

The right-of-way would make 10 crossings of creeks and rivers sufficienly large to support good stands of mature riparian spruce forests, the most productive forests of the area. Within the first 15 miles of the Interior Route in Canada (Figure 8.1.2.1-1) crossings are made of Potato, Surprise, and Schaeffer Creeks. Other crossings eastward are: Old Crow River crossed north of Old Crow at about Milepost 333; Driftwood River at Milepost 370; Rat Indian Creek at Milepost 374; the Bell River at Milepost 415; the Rat River at about Milepost 433; and Stony Creek and tributaries and unnamed streams between Milepost 440 and Fort McPherson.

Cut-grading of ice-rich soil materials and clearing at riverbanks would have major site-specific effects on riparian vegetation, usually tall shrub and spruce communities. Including the named larger streams, there would be crossings of about 58 streams. The area of destroyed vegetation at crossings, including minor drainages, is estimated to be about 100 acres. There would be greater destruction of vegetation at the proposed dual pipeline construction across the Peel River near Fort McPherson. This crossing is discussed as part of the proposed route (Section 3.1.2.6). The total impact, while major at the immediate crossing sites, would be minor in the short term at the site, as well as in relationship to the availability of vegetation of the types affected. Impact could extend into the long term if erosion control methods are not effective.

Warm Season Emergency Repairs

Unscheduled maintenance involving major repairs, such as of a ruptured pipeline, would require movement of heavy machinery from equipment pools at compressor stations. An emergency midway between two stations could require about 25 miles of travel either on or off the right-of-way. Low Ground Pressure (LGP) vehicles would cause the least damage but these too could be damaging to the revegetated right-of-way and to the numerous wet sedge and cottongrass tussock communities which might be crossed.

The active layer would be a few inches to a few feet deep depending upon a variety of factors, including kind of vegetation cover, kind of soil materials, thickness of peat, water content, and exposure. Under thaw conditions an active layer of any depth is sufficient for tracked vehicles to scar terrain, damage vegetation, and initiate more thaw. Such damages would be difficult and expensive to repair and their scars would remain for many years. The impact would be major wherever these emergency activities occurred along the Interior Route but cannot be predicted. In the long term, the cumulative effects of even infrequent events would have a significant impact on the appearance of the area, but the vegetation would ultimately recover.

Fire

The Forest-Tundra Formation has a moderate susceptibility to fire as do the specific low-shrub vegetation types crossed in the Alpine Tundra. Along the Interior Route much of the vegetation has such low biomass, or occupies such moist or wet sites, that its capability to sustain fire is limited.

Uplands covered with low shrubs, as well as the lower forested slopes, would be subject to frequent fires and the herbaceous tundra communities of drier sites would be expected to experience occasional burns. The riparian forests have low susceptibility to fire.

As pointed out in Section 3.1.2.6, there is a low probability that the pipeline project would increase the extent of fires, and a high probability that improved reporting and firefighting would reduce the areas burned. Along the Interior Route, as elsewhere in permafrost areas, summer firefighting entailing overland movement of heavy equipment would probably cause more vegetation and terrain damage than would the fire.

Air Pollution

Exhaust gases, especially the continuing short-term turbine emissions at compressor stations might have a deleterious effect on plants, especially lichens, as discussed in Section 3.1.2.6. Although natural gas is a clean-burning fuel, even the predicted low levels of sulphur dioxide emission requires further evaluation with regard to effects on the lichen winter food resource of caribou.

Ecological Reserves

The Interior Route would cross the full width of 140 miles of the proposed Canadian Arctic Wildlife Range (Figure 3.1.2.6-1) and, within its boundaries, about 70 miles of the Old Crow Flats IBP (International Biological Program) Site, including its mountain subsite, proposed for Ecological Reserve status by the IBP (Hernandez, 1974; Environment Protection Board, 1974, Vol. 3). The impact would be loss of wilderness character and deleterious effects on the ecosystems for which protection is sought.

Conclusions on Impact of the Interior Route

Although impacts on vegetation of one-third of the right-of-way would be severe during construction, total impacts after a few years would be minor to relatively moderate. Major effects include clearing of forest trees from the right-of-way, and the total loss of vegetation from 1,616 acres taken by permanent facilities and borrow pits. All other areas, 68 percent of the total of 4,988 acres of vegetation affected by construction (Table 8.1.2.1-3), would be subject to recovery in a few years to a few decades.

Major impacts would result from misuse of snow and ice roads, destruction of the thermal insulation provided by the moss-peat layer, disruption to drainage patterns, and from warm-season operation of emergency equipment along the thawed right-of-way or across country. In terms of the total vegetation resource these impacts would be moderate to minor.

Atmospheric pollution effects and fires, either of human origin or resulting from pipeline accidents, are predicted to have minor effects on vegetation.

Vegetation of the proposed Canadian Arctic Wildlife Range and Old Crow IBP Ecological Reserve would be moderately affected by direct impact of the pipeline project. In terms of the objective of preserving the ecosystems of these proposed reserves the project would have a major impact.

In terms of the effects of all project components on vegetation it is concluded that the impact of the Interior Route would be minor in the long term excepting the loss of wilderness qualities. The greatest impact would be the irrevocable impingement on ecosystems now remaining in their natural state.

Wildlife

Fish

Information presented in this section has been drawn from documents and reports listed in the "References." The reader is also referred to Section 3.1.2.7, the discussion of impacts along the proposed route. Almost all of the discussion presented there also applies to the Interior Route.

Along the Interior Route, most spawning and over-wintering areas would be downstream of pipeline construction and could be vulnerable to a reduced water supply or increased siltation. Turbidity and siltation from pipeline construction would be swept downstream into the Old Crow and Porcupine Rivers; both streams are spawning and nursery areas for several species of fish. The Porcupine drainage appears to have a greater abundance of fish and is more important to subsistence fishing, particularly for salmon.

Stream blockage would apparently create less of a problem to migrating fish along the Interior Route than along the proposed route because most of the spawning and over-wintering areas of the Interior Route are downstream from pipeline crossings. However, there would be a problem of repopulating upstream areas after the winter freeze.

It is hard to evaluate the probable impacts on the fisheries near the Interior Route that would result from depletion of dissolved oxygen and the development of eutrophication. Presumedly, the greatest danger would be to the substantial fisheries of the Old Crow and Porcupine Rivers downstream from the pipeline alignment.

Spills of fuel and other toxic substances would constitute a danger to fisheries along the Interior Route because important spawning and nursery areas are downstream from pipeline crossings.

Statements made concerning the potential impact of pesticide use on the area crossed by the proposed route are also applicable here.

The impact of increased human access during the construction phase would not be expected to differ greatly from that of the proposed route. During the operation and maintenance phase, conflicts could develop between utilization of the resource for sports fishing and for Indian subsistence fishing.

Mammals

Use of the Interior Route would have essentially the same general kinds of impacts on mammals as would use of the proposed route (Section 3.1.2.7). Potential impacts on individual species, however, would differ because of dissimilar conditions along the two routes (Table 8.1.2.1-4).

The Interior Route would avoid caribou calving grounds, which the proposed route would cross. Other influences, such as hunting and traffic on the Dempster Highway might, however, discourage caribou from use of winter range in the Ogilvie Mountains. Of about 10 migration routes determined by the Environment Protection Board (1974, vol.3), 3 cross the Dempster Highway.

The Interior Route would be more likely to encounter bear dens than would the proposed route. Construction activities and human presence could disturb bears, but if traditional dens were avoided adverse impacts on grizzly bears would be comparable on both the proposed route and the Interior Route.

The Interior Route barely skirts the Old Crow Flats and touches the Mackenzie Delta only peripherally. Consequently the impact on the substantial populations of beaver, muskrat, mink and otter in the aquatic habitats of the marshes and waterways would be minimal. The Interior Route would also essentially avoid the range of Dall sheep and the major portion of the Arctic fox denning areas.

Birds

The relative potentials for adverse impacts on birds along the proposed route and the Interior Route are summarized in Table 8.1.2.1-4. Considerations center on waterfowl, shore birds, and raptors, including endangered species (Section 3.1.2.7). Each of the routes would pass through or close to important habitat for these groups of birds. Approximately 70 miles of the Interior Route are through important habitat. The high bluffs adjacent to the Porcupine River and the north flank of the Old Crow Range are raptor habitat; the Old Crow Flats are second only to the Mackenzie Delta in production of waterfowl and shore birds and include the only known nesting areas for the endangered Tule white-fronted goose. The Interior Route alignment would not require overflights of the flats, and minor relocation of the alignment would substantially decrease the chances of pollutants being discharged into the flats.

Table 8.1.2.1-4 Comparative summary of environmental impact sensitivity for the proposed route and Interior Route for mammals and birds

	Proposed Route	Interior Route
Caribou	Crosses important calving grounds and is parallel to late spring movements along coast; operational aerial surveillance of pipeline and other activities could displace herds wintering in Richardson Mts. and disrupt calving and coastal movement.	Crosses migration routes between winter and summer ranges; human activities and travel on Dempster Highway could deflect migration from important winter range.
Dall Sheep	Close to important lambing and wintering areas for Richardson Mts.	Crosses southern edge of Dall Sheep range.
Moose	Crosses northern extent of moose range where habitat is critical; would restrict critical wintering areas along coastal streams.	Crosses range and lies between winter and summer range areas - winter construction would avoid conflict.
Grizzly Bear	Crosses coastal areas used by grizzly bears.	Crosses important grizzly bear range and through areas of traditional hibernation dens.
Marine Mammals, including Polar Bear	Could affect animals directly or through food by potential spills from handling, storage and transport of fuel.	Not near marine environment.
Waterfowl	Crosses most significant waterfowl production area in the Canadian Arctic (Mackenzie Delta - Yukon Coastal Plain); critical pre-migration habitat for very large flocks of snow geese, which are sensitive to disturbance by aerial flights and other construction activities; potential fuel spills and siltation damage to coastal regions and would be direct hazard to sea ducks.	Crosses Old Crow Flats, a very important waterfowl production area that contains only known nesting area for Tule white-fronted Goose, a rare and endangered species; proposed alignment would not require aerial overflights of the Flats and would pass along edge of production areas; minor alignment change would eliminate chance of pollutants being discharged on the Flats.

Ecological Considerations

The general nature of impact on ecosystems has been discussed for the proposed route (Section 3.1.2.8) and the effects mentioned are applicable to the Interior Route. Specific impacts discussed are applicable to the extent that the same ecosystems occur on both routes. They share the forest and tundra communities typical of the Forest-Tundra Ecosystem and the riverine and lake systems. The Interior Route includes the Alpine Tundra Ecosystem which is not found on the proposed route.

The aquatic systems are equally sensitive to siltation and chemical pollution on both routes but the effects at primary and secondary production levels in the food chain, or directly upon the fish, including their spawning success, would probably be more critical in streams of the Interior Route. This is true, not because the systems are more subject to degradation but because the fish fauna is more diversified and includes more species of value for subsistence and sport fishing. Siltation resulting from erosion induced by disturbance along side slopes of the mountain crossings could have deleterious effects on the riverine systems for several years. Winter construction as planned would expectedly hold stream crossing siltation to transient events and have little or no effect on the system.

Among terrestrial ecosystems, productivity would be reduced by the amount of communities displaced entirely by permanent facilities and the partial losses on areas of temporary construction disturbance where populations, excepting trees, would recover. Effects of productivity losses would be minor and short term in the major ecosystems.

The Alpine Tundra Ecosystem would be little affected by snow roads since rocky substrates are often prevalent at the surface or only veneered by thin, dry soils. Vegetation would be slow to recover naturally or by revegetation practices but the consequences to the soil thermal regime and integrity of permafrost would not be as severe as in the Forest-Tundra. The principal potential impact on the Alpine Tundra would be the disturbances of construction and operations on Dall sheep and of project operations on raptorial birds. Human presence and noise of machinery, compressor stations, blasting, and aircraft would have local effects on the behavior of sensitive animals and could be critical to nesting raptorial birds.

Two especially important ecosystem concerns are potential impacts on the Porcupine Caribou herd and the integrity of the Old Crow Flats. Winter construction extended into the early spring period of caribou migration could interfere with their arrival at traditional calving grounds in the tundra. The blocking of migration is avoidable and the predicted impact would probably be minor. Winter construction would obviate most concerns for migratory animals of the Old Crow Flats. If not rigidly controlled, aircraft noise in the operational phase would be disruptive to breeding success of highly productive bird populations. The hazard of pipeline rupture, with the potential of fire for a few miles on either side of the pipeline, would have major impact on terrestrial ecosystems, as would off right-of-way firefighting and repair efforts. The ecosystems probably would recover from such events within a few years and the consequences would be minor.

The major impact of the project on the Interior Route would be its intrusion into the shrinking amount of ecosystems in their natural state. Excepting the environs of Old Crow and Fort McPherson, the areas crossed by this route are essentially de facto wilderness. Along the route in the Yukon interior, the record up to 1972 demonstrates wilderness quality by the fact that only 1,650 acres had been disturbed by winter trails and seismic lines (Hernandez, 1974).

Economic Factors

The projected economic impact of a pipeline along the Interior Route would be much the same as that described for the proposed route. The only difference might be in the relative effects on Old Crow versus Aklavik because of proximity to the former community. However, the pipeline along either route would have some impact on both communities, and the same amount of labor would be required for either route.

It would appear that the impact of the Interior Route pipeline construction and operation on economic activities would be relatively greater in Old Crow than Aklavik because of its smaller size and more restricted economy. Existing businesses and services would need to be expanded and types not presently represented would be introduced to meet the demands of increased wage income and population that would almost surely result from the project. The new 5,000-foot airstrip at Old Crow would probably make the community a focal point for supply and distribution of men and material. If a highway were extended into Old Crow, which is relatively isolated from the rest of the region, land-transportation-related economic developments would no doubt follow.

In view of the demonstrated predisposition of the people of Old Crow to seek wage employment, it would seem likely that more of the local residents would take jobs on a pipeline project if it were close at hand than if the route were over 100 miles away. A considerably larger income might remain in the community providing a more viable economy and a broader local tax base; the migration of residents to larger communities would probably decrease.

The economic development would probably be greatest during the pipeline construction phase and continue at a reduced pace in the operational phase. In the operational phase, employment would be greater in the communities closest to the pipeline. The trend of concurrent economic activity in hunting, trapping and fishing would be uncertain and dependent upon whether the residents viewed these activities as recreational, part- to full-time business, or out-moded pursuits.

Some undesirable effects might result in Old Crow if a pipeline is built in the immediate area and relevant preventive measures are not taken. The economy might go through a "boom-and-bust" cycle, leaving the community with a reduced economic base following the construction phase. Some damage to the land-related economy could result if construction and operation activities drive game from the area.

If the pipeline is not built along either the proposed route or the Interior route, petroleum exploration activities will probably be curtailed or cease entirely. This would remove the major economic support that Old Crow has had in the past 10 years.

Sociological Factors

If a pipeline were built along the Interior Route close to Old Crow, the population of the community would probably increase because access to local wage employment would encourage people to remain, former residents to return, and new residents to move in. If the pipeline were built along the proposed route, the population of Old Crow might be expected to remain about constant or to decrease slightly over the next 10 years. If neither project materializes, the population of Old Crow is apt to decrease in the next decade, barring other unforeseen development. The manner in which the pending Native land claims settlement is resolved may have an effect on the community population in either direction.

In the field of housing and community services, a pipeline along the Interior Route if built, would have a stimulating effect owing both to need and to availability of money. Presumably an increased tempo of activity might encourage more government-subsidized participation in the needs of the community. Currently, housing is apparently adequate but would probably not suffice for an appreciable increase in population. Services would need to be improved in any event, and apparently a start has been made to upgrade water, sewage, and garbage handling. If the pipeline were built, the projected population growth would require better utility services. If the project did not materialize or if it followed the proposed route, probably only slow and modest improvements could be expected in utility services.

Current differences in local opinion about the pipeline development make future projections of the residents' attitudes very uncertain. According to past records of local meetings, some people have flatly rejected the pipeline, while others have demanded that it be built. Survey interviews in 1973 indicate that some of the people favor the proposed route in order to keep activity out of the Old Crow Flats. Others are concerned about encroachment on hunting and trapping areas, but feel that petroleum exploration and the Interior Route pipeline would be acceptable if strictly controlled.

Land Use

The discussion of possible impacts on land use along and near the northern part of the proposed route (Section 3.1.2.11) is also applicable to possible impacts on land use in the area traversed by the Interior Route. In addition to land clearing on the proposed right-of-way and for ancillary installations such as compressor stations, borrow pits, and the like, activities during the construction phase of the project might cause some change in the migration patterns of the Porcupine caribou herd and its use as a source of meat. After completion, the pipeline should have no significant impact on the herd and its movements.

Paleontological, Archeological, and Historic Values

Every aspect of the project that involves a land-use activity could cause loss of, or damage to, the archeological resources of the region. Construction of auxilliary features such as compressor stations, borrow pits, stockpile sites, and wharves, as well as the excavation of the pipeline trench itself, could destroy potential archeological and historical sites. While the Interior Route would not come in direct contact with any of the high priority sites identified by Millar (1974) or any sites identified in archeological publications, it would traverse an area of great archeological potential. The area around Old Crow is virtually unknown archeologically, but evidence of early man has been found there (Irving and Harington, 1973).

Construction of a pipeline along this route could greatly facilitate access to archeological sites by archeologists, but the destructive effects of increased access by the general public should also be considered. While construction could destroy potential archeological sites, it could also uncover many sites, provided proper salvage measures were undertaken.

Recreation and Esthetic Resources

Although recreation resources along the Interior Route are largely undeveloped, construction of the project could adversely affect some potential recreation areas. Any pipeline operation that altered or impeded movements of the Porcupine caribou herd would interfere with the realization of its recreation potential and would be considered a major impact.

From the air, a cleared pipeline right-of-way would look like an extra-wide seismic line except in the exposed rock areas. The impact on low-level aerial viewing and photography would be severe, especially where the Interior Route is close to the Porcupine River or where it would cross the Rat River-Stony Creek Pass through the Richardson Mountains. For on-the-ground viewing and photography, the cleared right-of-way and particularly the proposed compressor station in the Rat River-Stony Creek Pass would detract from the scenic value of the pass. If a satellite communication system is not utilized, the transmission towers proposed by the Applicant would occupy prominent peaks and hence could interfere with scenic viewpoints.

Air Quality

The discussion of possible impacts on air quality along the proposed route (Section 3.1.2.14) is applicable to possible impacts along the Interior Route. Minor atmospheric pollution would be the only impact; at worst it would be local and transitory.

Environmental Noise

Noise impacts along the Interior Route would be similar in nature and magnitude to those along the proposed route north of about 59° N latitude; see Section 3.1.2.15.

8.1.2.2 Cross-Delta Route

The Cross-Delta Route is identical to the proposed route except for alternative segments of the Prudhoe Bay Supply Line, the Richards Island Supply Line, and the Main Line between Shingle Point, Richards Island, and Thunder River (Figure 8.1.2-1). Only these alternative segments are discussed here.

The Cross-Delta Route would diverge from the proposed route near Shingle Point at about Milepost 291 (Figure 8.1.2.2-1) and would approximately parallel the proposed route to Milepost 319 where it enters the Mackenzie Delta. The route then runs across the Mackenzie Delta to Tununuk Junction (Milepost 372) where it joins the Richards Island Supply Line.

The Cross-Delta Route would include a revision of the Richards Island Supply Line. From the origin near the north end of Richards Island, the revised supply line would run southward along the west side of Richards Island to Tununuk Point near Milepost 19 (Figure 8.1.2.2-1). From this junction, the route would extend southeastward and rejoin the proposed route at the Parsons Lake Junction near Milepost 43. From here to Milepost 71, the route is identical to the proposed route. At Milepost 71, the Cross-Delta Route diverges from the proposed route and runs southeastward to rejoin it near Thunder River at Milepost 172. The Cross-Delta Route from Shingle Point, Richards Island, and Parsons Lake to Thunder River would total about 269 miles, compared to the total mileage of about 407 for the proposed route.

Description of the Existing Environment

Climate

The climate of the Cross-Delta Route is essentially identical to that of adjacent portions of the proposed route (Section 2.1.2.1).

Topography

The topography of the Cross-Delta Route is discussed under "Physiography" in the following section.

Geology

Physiography

Bostock (1970) subdivided the area containing the Cross-Delta Route into 3 major regions: the Arctic Coastal Plain, the Mackenzie Delta, and the Anderson Plain. These regions together with a more detailed subdivision of the Mackenzie Delta area by Mackay (1963) provide a convenient framework for discussion.

Arctic Coastal Plain--The Arctic Coastal Plain is a region of low relief and generally gentle gradients that in this area extends from the Richardson Mountains to the Beaufort Sea. The general elevations, slopes, total relief, and local relief along the Cross-Delta Route are similar to those described for the proposed route.

From the junction with the proposed route to near the Blow River at Milepost 306, the Cross-Delta Route ranges from about 200 feet to 300 feet in elevation across a gently rolling surface. Slopes are gentle except at stream crossings where moderate to steep slopes occur and local relief of 10 to 20 feet is present. Streams crossed on this portion of the route are Conglomerate Creek, Deep Creek, Walking River and Tundra Creek.

At Milepost 306, the route descends gentle to moderate slopes to the valley of the Blow River, which is incised from 150 to 200 feet below the level of adjacent areas. The elevation of the floodplain at the river crossing is about 50 feet. From the floodplain, the route ascends a steep slope to a river terrace at an elevation of about 90 feet, and then ascends a second steep slope to a level area at an elevation of approximately 220 feet. The route then crosses two tributaries of Rapid Creek, which are incised about 140 feet below the level area. At Milepost 310.5, the route descends steep slopes to the valley of Rapid Creek, which is at an elevation of roughly 75 feet. On the east side of Rapid Creek, the route rises abruptly to an elevation of roughly 420 feet. At Milepost 314, the route descends moderate to steep slopes to an elevation of 250 feet. The route then traverses an area of somewhat irregular terrain with local relief of 30 to 50 feet, which ascends gradually to an elevation of 300 feet. The route remains at an elevation of 300 to 330 feet until Milepost 318. At this point, the route descends moderate slopes to Milepost 319 where it drops abruptly 130 to 150 feet to the Mackenzie Delta.

Mackenzie Delta--Between Mileposts 319 and 372, the route crosses the islands and channels of the modern Mackenzie River Delta. The elevation of the route is near sea level throughout this region, and slopes are flat except at channel crossings. There are approximately 8 miles of channel crossing which range in length from a few hundred feet to 4.5 miles.

Rolling to hummocky terrain characterizes the Richards Island Supply Line and the Cross-Delta Route from as far as Milepost 0 to Milepost 42.5. North of East Channel, near Milepost 29.5, elevations are generally less than 100 feet and local relief ranges from 25 to 75 feet. From Milepost 29.5 to Milepost 42.5, local relief ranges from 25 to 100 feet and elevations range from 100 to slightly more than 200 feet. Gentle to flat slopes are common, but short segments of steep slopes are present in hummocky areas.

From Milepost 42.5 to Milepost 86, the route traverses the Caribou Hills, a rolling to hilly area containing broad meltwater channels. Elevations along this portion of the route range from 200 to 800 feet. Local relief ranges from 50 to as much as 200 feet, but is generally less than 100 feet. Although most slopes are gentle, steep slopes sometimes occur at channel margins.

The Campbell Lake Hills region of Mackay (1963) extends from Milepost 86 to Milepost 105. Between Mileposts 86 and 93.5, the terrain is quite flat with elevations of 30 to 60 feet. From Milepost 93.5 to Milepost 102.5, the route ascends gradually to a maximum elevation of slightly more than 1000 feet. From Milepost 102.5 to Milepost 105, the route traverses rolling terrain with elevations ranging from 850 to 950 feet. Local relief along this portion of the route ranges from 20 to 50 feet and slopes are generally gentle.

From Milepost 105 to Milepost 113, the route crosses a small portion of the area designated as "Unfluted Plains" by Mackay (1963). The terrain is gently rolling and elevations range from 850 to 950 feet. Slopes are gentle and local relief ranges from 10 to 25 feet.

In the Hyndman Lake Hills region, Mileposts 113 to 126, the route passes through hilly terrain with many lakes. Elevations range from 700 feet to slightly more than 900 feet. Slopes are gentle except along the margins of thermokarst depressions where steep slopes occur. Local relief ranges from 20 to 75 feet.

Anderson Plain--The portion of the Anderson Plain crossed by the Cross-Delta Route is hummocky to rolling terrain. Between Mileposts 126 and 138.5, the elevation along the route varies from about 500 feet to slightly over 900 feet, and local relief is from 50 feet to 75 feet. From Milepost 138.5 to Milepost 149, the route crosses hummocky terrain with local relief of 50 to 75 feet. Elevations on this portion of the route range from 450 feet to about 600 feet. At Milepost 149, the terrain becomes more hilly and there is a greater range in elevations until about Milepost 165. Here elevations range from about 600 to nearly 900 feet. From Milepost 165 to the junction with the proposed route, the elevation varies from 400 to 500 feet. Local relief along this part of the route is generally less than 25 feet. Slopes are gentle, except for short segments of steep slopes at the margins of thaw lakes and at some drainageways.

Bedrock

Beneath the Arctic Coastal Plain along the Cross-Delta Route (Mileposts 291 to 319), bedrock consists of Jurassic and Cretaceous shale, siltstone and sandstone. In general, depth to bedrock ranges from 5 to 70 feet, but in places bedrock may lie at greater depths. These rocks are mainly incoherent, easily eroded, and subject to slumping where exposed. Bedrock is exposed in the valleys of Blow River and Rapid Creek.

From Milepost 319 to 372 where it joins the Richards Island Supply Line, the Cross-Delta Route crosses the Mackenzie Delta. In this region bedrock lies at a depth of several hundred feet beneath deltaic and glacial deposits.

The Cross-Delta Route (including Richards Island Supply Line) crosses unconsolidated Quaternary deposits between Mileposts 0 and 44, and the depth to bedrock is unknown. From Milepost 44 to the terminus at Milepost 172 bedrock lies at depths ranging from a few feet to a few tens of feet beneath morainic deposits. In places, the slope of the surficial deposits is bedrock controlled. The approximate distribution of the bedrock units is as follows:

Milepost 44 to 75. Tertiary Reindeer Formation; sand, silt and shale which are poorly consolidated and interbedded with coal; soft, easily eroded, subject to slumping; occur within a few feet of the surface from Milepost 44 to 52.

Milepost 75 to 97. Cretaceous shale and siltstone; incoherent rocks, soft, easily eroded, subject to slumping; occur within a few feet of the surface from Milepost 80 to 82.

Milepost 97 to 172. Undifferentiated shale and sandstone, either Cretaceous or Devonian Imperial Formation; either lithology could be encountered at a given point, but available data do not permit separation; bedrock exposed in places from Milepost 120 to 150.

Surficial Deposits

With the exception of the modern Mackenzie Delta, the kinds of surficial materials traversed by the Cross-Delta Route are the same as those described for the proposed route (Milepost 291 to 330, Prudhoe Bay Supply Line and the Richards Island Supply Line).

Morainic, glaciofluvial, and glaciolacustrine deposits predominate between Mileposts 291 and 319. The sediments are typically ice-rich, silty to clayey, and locally contain as much as 20 percent gravel. Organic cover above the glacial deposits ranges in thickness from a few inches to 15 feet. Farther east, between Mileposts 319 and 372, interbeded ice-rich deposits of silt, clay, fine sand, and organic material characterize the Mackenzie Delta.

Interbedded ice-rich silt, clay, fine sand, and organic matter of the Mackenzie River Delta occur between Mileposts 0 and 3 and between Mileposts 18.5 and 21.5. These sediments alternate with ice-rich morainic and lacustrine deposits, which extend between Mileposts 3 and 18.5 and between Mileposts 21.5 and 85. The morainic deposits consist of gravelly silt and clay with some sand. The lacustrine deposits, which fill kettle and thermokarst depressions, consist of silt, clay, and fine sand. Organic deposits several feet thick overlie lacustrine sediments and occupy low areas of morainic deposits. From Milepost 40 southward, the morainic deposits form a veneer over bedrock, and may be less than 7 feet thick in places. Between Mileposts 85 and 95, ice-rich lacustrine and fluvial silt and sand occupy the abandoned course of a Pleistocene(?) river. The lacustrine deposits generally are overlain by several feet of organic materials. Hummocky moraine with lacustrine deposits in kettle depressions again predominates between Mileposts 95 and 172. Their lithologies are comparable to those described for morainic and lacustrine deposits farther to the north. The morainic deposits are thin between Mileposts 120 and 150, and bedrock is exposed in places.

Mass Movement and Erosion

All surficial deposits along the Cross-Delta Route contain ice-rich permafrost and are subject to rapid degradation if the thermal regime is naturally or artificially altered. Where streams impinge upon surficial deposits, thermokarst degradation occurs during the summer in the form of slumping and flowage. Slumps and debris flows are also common along lake basin margins. Where slopes reflect bedrock control, active layer detachment failures are sometimes present.

In the modern Mackenzie Delta, channel shifting may be an important cause of erosion. Mackay (1963; fig. 59, p. 129) identifies the area traversed by the Cross-Delta Route as a region where channel shifting has occurred which is recent enough to map from air photos. Although channel shifting does occur, extensive channel shifting may not have been common during the past several hundred years (Mackay, 1963). This inference is drawn from the presence of mature spruce lining channels in the southern part of the delta, and from the presence of irregular lakes and well-developed ice wedge polygons. Extensive bank modification can occur during spring breakup, as ice is shoved along the bank like a bulldozer.

All shale and siltstone bedrock units, and the poorly consolidated sand, silt and shale of the Tertiary Reindeer Formation are soft, easily eroded, and subject to slumping and debris flows.

Permafrost

The Cross-Delta Route lies within the zone of continuous permafrost. The modern Mackenzie Delta, however, may represent an outlier of the discontinuous zone (Smith and Hwang, 1973). The frozen surficial deposits traversed by these routes are dominantly ice rich. Visible ice in stratified or distinctly oriented ice forms is recorded in most of the logs of borings along the route supplied by the Applicant, and massive ice was sometimes encountered. Along the Arctic Coastal Plain, excess ice is commonly reported to depths of 25 feet (Rampton, 1971). In the Mackenzie Delta, the ice content may exceed 50 percent for several tens of feet (Pihlainen and others, 1956).

Mackay (1967) reports permafrost thickness at the distal end of the Mackenzie Delta to be 60 to 100 feet. On the basis of temperature measurements made with thermister cables installed in shot holes, he concluded that permafrost there is aggrading downwards. The thickness of permafrost along the Cross-Delta Route, farther from the coast, is probably greater than 100 feet. However, zones of unfrozen sediment occur beneath major channels and deep lakes, and Gill (1973) believes that unfrozen ground may underlie a significant portion of the subaqueous delta.

Mineral Resources

Other than sand and gravel, no known metallic or nonmetallic mineral resources lie within 150 miles of the Cross-Delta Route.

Significant oil and gas deposits are described in Section 2.1.2.3.

Seismicity

The seismicity of the region containing the Cross-Delta Route is discussed in Section 2.1.2.3. Potential seismic risk can be summarized as follows:

Length of Segment (miles)	Magnitude of maximum expectable earthquake
82	5.5
187	5.0

Soils

Soils along the Cross-Delta Route are identical to those described for the "Prudhoe Bay and Richards Island Supply Line" in Section 2.1.2.4. Poorly drained tundra soils (Gelic Gleysols) predominate, the Gelic Regosols occur on slightly higher and better drained sites.

Water Resources

Surface Water

The Cross-Delta Route lies entirely within the Arctic Coastal Region. Streamflow data are not adequate to determine magnitude and variability of flow. Floods are predicted to occur as the result of snowmelt and may be increased by ice jams. Summer rainstorms may cause some flooding in channels along the western edge of the delta, especially if the headwaters originate in the Peel or Arctic Red River drainage.

During the winter, some of the channels may have no flow and many of the shallow lakes and wetlands will be completely frozen.

Some additional information may be found in the Babbage Bight Corridor Description (Section 8.1.2.3).

The streams which flow into the Mackenzie Delta contain soft to moderately hard bicarbonate-type water. Concentration of dissolved solids for the streams reported by the Department of Environment, Canada (Bryan, 1973) in 1971-72, ranged from 44 to 253 mg/l. Water quality data from some lakes in the Mackenzie Delta region are considered to be representative (Brunskill et al., 1973a, b). Specific conductance ranged from 88 to 950 micromhos per centimeter. Dissolved oxygen values range from 0 to near saturation. The lakes were nearly anaerobic under late winter ice cover but rapidly became supersaturated with oxygen in August and September, according to the report. Little or no data are available on the sediment concentrations of the streams in this region. Estimates of suspended sediment discharge for high flow have been made by Howard (in Environment Protection Board, 1974, vol. IV, pp. 177-204), which indicates that sediment concentrations are low (less than 50 mg/l) in most streams. Suspended-sediment data collected from June to September 1973 on the Firth River seem to indicate that sediment concentrations can be rather high (more than 600 mg/l) during high runoff events (Davies, 1974). However, from the very small amount of information available, streams draining this region carry little suspended sediment during normal to low flow. No information is available on winter sediment concentration, but from experience in other areas of the Arctic, suspended-sediment concentrations are usually very low under ice cover.

Ground Water

The Cross-Delta Route lies entirely within the continuous permafrost zone. Although most of the region has been glaciated and the clastic material in these deposits range in size from fine glaciolacustrine silt to coarse outwash, development of ground water in the area has not occurred, and the quality of the ground water is unknown. Analyses of winter flows from some of the rivers indicate a bicarbonate-type of water with fairly low concentrations of dissolved solids (McCart, 1974).

Vegetation

The route would lie within two formations, the Tundra and the Forest-Tundra. The Cross-Delta Route, from its point of divergence from the proposed route near Shingle Point, Yukon Territory (Figure 8.1.2.2-1), would cross Herbaceous Coastal Tundra (Figure 8.1.2.1-2) to about Milepost 355. From here to Tununuk Junction and from Mileposts 0 to 71 (Noell Lake), the route would cross Low Shrub-Heath Tundra. From Noell Lake to the junction with the proposed route at Thunder River, the pipeline would lie within the Forest-Tundra Formation. The discussion of vegetation is based primarily upon Hernandez (1974) and Canadian Arctic Gas Pipeline Limited (1975a).

Herbaceous Coastal Tundra

Yukon Coastal Plain--The plant communities of the coastal plain have been previously discussed (Section 2.1.2.6). In brief, the vegetation is predominantly of plants of the grass lifeform (grasses and sedges), usually on wet, highly organic terrain, everywhere underlain by permafrost with only a shallow surface layer (active layer) subject to warm season thaw. Wet sedge meadows occupy the lower, flat areas characterized by numerous ponds and lakes and usually patterned by an array of ice-wedge polygons. Depending upon the degree of thermal erosion of ice wedges, the polygons may have depressed centers surrounded by low ridges or if erosion has been deep the polygon centers remain as mounds surrounded by ditch-like troughs. In either case, the lower wet areas bear wet sedge meadow type communities and the relatively more elevated areas may be either communities of grasses, herbs, mosses and lichens or of low-growing dwarf shrubs. The latter include several species of willows and such heaths as Labrador tea, bearberry, lingonberry, and crowberry. Peat moss (*Sphagnum* spp) and other mosses are usually present and contribute significantly to the accumulation of organic material and the protection of frozen soils against deep thawing.

On more elevated terrain of the low, rolling foothills cottongrass tussock communities predominate, usually with a component of low shrub-heath species. Cottongrass tussock vegetation occupies about 30-35 percent and wet sedge meadows 20-25 percent of the terrain along the 30 miles of the route from Shingle Point to the Mackenzie Delta.

Along streams feltleaf willow, other species of willow, and alder form tall shrub communities. Related to flooding levels, stream margins and flood plains exhibit a diversity of pioneer communities and successional stages of herbaceous species.

The Mackenzie Delta--On the low alluvial islands of the delta the tundra communities are of the same types as on the coastal plain. The flat, poorly drained, frequently inundated surfaces which predominate produce a shift toward the wet sedge meadow communities and a decrease in both cottongrass tussock and low shrub-heath communities.

Wet sedge meadows are estimated (CAGPL, 1975a) to cover 75% of the route area to Middle Channel, Mackenzie River (approximately Milepost 355). The tall shrub communities of willow and alder are accompanied by balsam poplar, in some cases, or poplar may occur as small, scattered clumps.

Low Shrub-Heath Tundra

These communities have been discussed in Section 2.1.2.6. Table 2.1.2.6-2 gives the distribution of communities for the areas about Eskimo (Husky) Lakes, the Caribou Hills, Tununuk Point and Tuktoyaktuk. About 102 miles of right-of-way would cross vegetation that is predominately of low, woody shrubs.

The communities are a complex of heaths (Labrador tea, lingonberry, bearberry, crowberry and alpine blueberry) or heaths and dwarf birch and dwarf willows. On midslopes and upper slopes these assemblages cover 75-90 percent of the ground. There is a more limited distribution of cottongrass tussock and wet sedge meadow communities, and riparian tall shrub communities of willow and alder occur along most drainage ways.

Forest-Tundra

About 100 miles of right-of-way, from Noell Lake to Thunder River (Figure 8.1.2.2-1), crosses communities of this formation as previously described (Section 2.1.2.6). The Forest-Tundra boundary occurs near Noell Lake where the tree line is marked by scattered distribution of black spruce. The vegetation is dominantly low shrub-heath with scattered black spruce for 20 miles of this segment. Southward there is an increased occurrence of spruce and the appearance of occasional clumps of open spruce forest with an understory of willows and heaths. Open spruce forests increase in coverage to the south and along drainage ways closed forest are formed. The open spruce forests of the uplands characteristically have a ground cover of foliose and fruticose lichens important to winter food supply of caribou. White birch has a scattered distribution on hilltops in the last 25 to 30 miles to Thunder River.

Throughout this segment tall shrub communities of alder and willow occur along stream courses. Wet sedge meadow communities occupy the low, wet areas which are usually patterned by ice-wedge polygons. Sedge fens occur occasionally and there is a more limited distribution of peat bogs.

Wildlife

Fish

The fishery resource along the part of the Cross-Delta Route west of the Mackenzie Delta is essentially the same as the proposed route. Where the route crosses the delta, it would intercept areas of abundant fishery resources. It is likely that the delta is the most important fishery resource traversed by the entire pipeline. The route through the delta crosses many channels and the 4.5 mile wide Shallow Bay which is used as migration routes, spawning, rearing, and over-wintering habitats. Grayling, pike, and burbot appear to remain in the delta throughout the year. Arctic char and whitefishes, inconnu, cisco, and probably others use the bay and channels as migratory routes. Between Noell Lake and Thunder River, the route crosses areas near Lost Reindeer Lake with important fishery resources. This region includes many shallow and deep lakes. Travaillant Lake is one of the largest lakes in the region. Many of these lakes contain whitefish, grayling, lake trout, and cisco. They can be expected wherever there is water or access to water favorable for over-wintering.

The route crosses several major streams which provide over-wintering conditions. A tributary of Sitidge Lake and Travaillant River are the largest. Travaillant River appears to be excellent grayling habitat. Other species likely to be present in these larger rivers are pike, longnose sucker, and smaller species such as sculpins and lake chub. The smaller streams are not as important as year-round habitat as most freeze to the bottom during winter. However, it is likely that many provide migratory routes and spawning areas.

Mammals

Most of the same species inhabit the Cross-Delta Route as inhabit the proposed route. Most would be impacted and present the same kinds of mitigating problems. There are, however, three significant differences.

The Porcupine caribou herd migrates along the west side of the Mackenzie Delta and would be impacted by the proposed route. The herd does not commonly inhabit the area of the delta where this route crosses it.

Richards Island appears to be inhabited by a larger number of grizzlies than other areas in the region. Most of these bears are sows with cubs and many dens have been located. The length of the right-of-way of the Cross-Delta Route would be about 4 miles longer than the proposed route on Richards Island.

Shallow Bay, which would be crossed by 4.5 miles of dual pipelines, is used by beluga whales. Most leave the Bay by the end of the first week of August. The whales would be impacted either directly by construction or indirectly by habitat alterations. The proposed route does not cross whale habitats. This is probably the most significant difference between the two routes concerning mammals.

Birds

The Mackenzie Delta and adjoining area extending west along the coast into Alaska is one of the most important waterfowl regions on the North American Continent. Ducks, geese, and swans use the region for nesting, molting, feeding, and staging for migrations. The larger species include snow geese, Canada geese, white-fronted geese, whistling swan, and the rare trumpeter swans. These larger waterfowl tend to concentrate in the outer delta whereas most ducks are distributed throughout the delta region. The Cross-Delta Route would traverse the delta through an area of critical importance to many of those larger waterfowl species. In addition, a compressor station would be located in an area critical to some species at Milepost 357.

The delta is also important to many other birds such as loons, grebes, curlew, gulls, terns, bald eagle, and many others. The endangered peregrine falcon is present and the endangered Eskimo curlew may still be present. The delta was an historical meeting area for this species and is prime habitat for expansion. Most of these species would be impacted by either the proposed route or the Cross-Delta Route. Between Noell Lake and Thunder River, there are areas of important bird habitat, especially waterfowl, in the vicinity of Travaillant Lake.

Ecological Considerations

The major ecosystems affected include the Marine Inner Continental Shelf; Marine Ice Affected Coast; Freshwater Lake and Riverine; Herbaceous Coastal Tundra; Low Shrub-Heath Tundra; and Forest-Tundra. The general relationship of ecosystems and specific relationships of the systems under considerations here have been previously discussed (Sections 2.1.2.8 and 3.1.2.8) and are applicable to the Cross-Delta Route.

The same major ecosystems would be affected as on the proposed route but in differing degree. There would be a large increase in the mileage of Herbaceous Coastal Tundra Ecosystem crossed, much of it by a dual pipeline. Elimination of the proposed route from Shingle Point to Thunder River vastly reduces effects on the Forest-Tundra Ecosystem. There is a further reduction of effect on Forest-Tundra since the Noell Lake to Thunder River segment of the pipeline from Richards Island is shorter than the Noell Lake-Travaillant Lake-Thunder River alignment. The Cross-Delta Route, however, crosses more critical wildlife area in the Travaillant Lake region. Both marine and freshwater ecosystems would be more seriously affected on the Cross-Delta Route than on the proposed route. Crossing of Low Shrub-Heath Tundra Ecosystem would be about equal by either alignment.

The most important ecological implications of the crossing of the Mackenzie Delta are the large potential disruptions of interrelationships of a physical-biological complex that is itself a unique ecosystem. Little is known of the intricate marine, freshwater and terrestrial interrelationships within the Mackenzie Delta Ecosystem but it must be assumed to be in a stable, dynamic equilibrium little affected by human influences. The delicacy of the balanced ecosystem is not known and the cumulative effects of the proposed and related projects cannot be rationally predicted. The delta is one of the most highly productive ecosystems in the Canadian Arctic. Its renewable resources are the base for hunting, trapping and fishing activities which are significant to Native peoples for subsistence as well as for the pursuit of cultural traditions.

Social and Economic Factors

The social and economic factors relating to the entire proposed route have been described at length in preceding chapters and will not be repeated here. In large part these factors are not specifically site related, and the previous analysis can be appropriately applied to the Mackenzie Delta subregion in which both the proposed and Cross-Delta routes are located.

Land Use

Land use is similar to that of the northern part of the proposed route (Section 2.1.2.11). The land is a quasiwilderness used mainly to provide the subsistence base for a largely hunting and gathering economy of Native peoples. Barge traffic during the summer, activities related to petroleum exploration along the eastern margin of the Mackenzie Delta, and aerial overflights have been the major activities other than hunting, fishing, and trapping.

Paleontological, Archeological, Historical

As the Cross-Delta Route coincides with the proposed route except between Shingle Point and Parsons Lake Junction and between Noell Lake and Thunder River, the reader is referred to Section 2.1.2.12, which deals with the archeological, paleontological and historical resources of the proposed route. In the Mackenzie Delta area, a few archeological sites along the route of the Cross-Delta alternative have been investigated (Cinq-Mars, 1973), including the following:

Rapid Creek (two sites)

West of Whitefish Station

East side of channel at Tununuk

Nennorai Point

Probable hunting site locations along the coast line include terraces near river mouths and the shores of coast-side lakes. Probable campsites include sand spits, storm beaches, river mouths and protected bays with terraces. On the coastal plain, any high terrace, scarp, or erosional remnant could have served as lookout stations for game, and river banks or well-drained lake shores could have been fishing stations. Probable campsites on the coastal plain include well-drained lake or river terraces and depositional glacial features, particularly along lakes or streams or near lookout stations (Millar, 1974).

Recreation and Esthetic Resources

The Cross-Delta Route passes through three physiographic regions: the Arctic Coastal Plain, the Mackenzie Delta, and the Anderson Plain. The Arctic Coastal Plain, when viewed from the air, is composed of gently rolling hills that are bounded by the British and Richardson Mountains to the south, and which taper off into the far-reaching horizon of the Beaufort Sea to the north. On the ground, the low profile vegetation does not obscure vision; however, the view is sometimes limited by the rolling, dissected topography.

The Mackenzie Delta as seen from the air is a braided network of channels surrounding numerous lakes. On the ground in the southern portions of the delta, vision is obscured by the tall spruce which line the levees of the channels and lakes. Relief seldom exceeds ten feet. The northern portions of the delta are generally level with little surface relief and only low shrubs, sedges, and grasses.

The Anderson Plain, when viewed from the air, is composed of sharply rolling hills dotted with scattered clumps of trees. To the west, the view consists of the flat expanse of the Mackenzie Delta with the Richardson

Mountains on the horizon. The view on the ground may be limited by general topography. The vegetation is generally low and scrubby, with only scattered stands of coniferous or deciduous trees.

While there are no official recreation areas or facilities along the Cross-Delta Route, there are natural areas and features of potential value for recreation in the vicinity. Some of the major recreation activities that can be enjoyed in the area include sightseeing and photography, wilderness use, hunting, fishing, camping, boating, and nature study. The Mackenzie Delta is an important fisheries area and is considered to be one of the most productive waterfowl areas in the western Arctic. Moose occur seasonally throughout much of the region.

Evaluation of the Environmental Impacts

Climate

Climatic effects of construction and operation of a pipeline within the Cross-Delta Route would be minimal. Local ice fog conditions would be the principal climatic impact (see Section 3.1.2.1).

The impact of the severe arctic climate on the project would be essentially identical to those described for the proposed route (Section 3.1.2.1).

Topography

A discussion of the impacts on topography is included within the following section.

Geology

With the exception of the portion of the Cross-Delta Route that traverses the modern Mackenzie Delta (Mileposts 319 to 372), the effects of pipeline construction and maintenance are similar to those described for the proposed route north of Thunder River. These effects include terrain scars resulting from the extracting of natural construction materials, drainage disruption (surface and subsurface), instability of slopes, accelerated erosion, thawing of permafrost and the effects of a cold buried pipeline, seismic effects and impacts on mineral resources. They have been discussed in Sections 3.1.2.2 and 3.1.2.3.

As with the proposed route in the Mackenzie Delta region, the Cross-Delta Route would have a high to very high SPG Index (see Section 3.1.2.3). Potential geological impacts could be severe along almost the entire length of each route.

Although the nature of the impacts of construction and maintenance are similar for both routings, the change in alignment and 139 mile decrease in right-of-way mileage has the following effects: (1) elimination of two major river crossings, the Peel crossing and the Mackenzie crossing at Point Separation; (2) the number of necessary borrow pits would be reduced from 34 to 17; (3) the number of miles of high to very high adverse impacts related to slopes, permafrost, and geology would be substantially reduced.

In the modern Mackenzie Delta, impacts of the pipeline upon topography and geology and impacts of topography and geology upon the pipeline can be grouped into 3 categories: (1) those related to permafrost and the thermal regime; (2) those related to the deltaic environment, and (3) those related to seismicity.

Alteration of the thermal regime could pose serious problems in the Mackenzie Delta even though the area is essentially flat. Removal of vegetation or damage to the organic mat will cause changes to the thermal regime that could result in thawing of permafrost. Thawing of permafrost and increased thickness of the active layer might result in settling, caving, subsidence, flowage or all of these. Deltaic materials beneath major channels are not permanently frozen, and a frost bulb around the pipeline produced by the flowage of chilled gas could produce frost heave. Any of these events could cause damage to the pipeline and some could cause irreversible damage to the terrain.

Possible problems related to the deltaic environment include: channel shifting, scouring and bank erosion, and flooding. The Cross-Delta Route traverses a region that Mackay (1963) identified as having had channel shifting recent enough to recognize on air photos. Major channel shifts, however, may not have occurred within the past 200 to 300 years. Nevertheless, bank erosion does take place, and should be considered in the design of pipeline facilities, especially in the eastern portion of the delta where currents are likely to be strongest. The maximum depth of scour during spring floods should be determined as the pipe must be buried below this level.

All low-lying land along the route in the Mackenzie Delta is subject to flooding by high river stages, ice jamming, and storm surges. The maximum depth of flooding to be expected during such events should be ascertained, and pad heights and surface facilities designed accordingly.

Although the nearest large seismic events of record have been placed in the vicinity of Fort McPherson, about 200 miles south of the Cross-Delta Route, the period of record is short and possible errors in the positioning of epicenters is large. The possibility of strong seismic shaking, therefore, should not be discounted. In addition to the direct effects of strong shaking, geologic consequences that could affect the pipeline are liquefaction and differential compaction. The silty deltaic materials beneath major channels are unfrozen, and liquefaction and attendant flotation of the pipe should be considered at these sites. Strong shaking could cause differential compaction of the interbedded silty, sandy, and organic deltaic materials beneath the permafrost which might produce differential subsidence of the upper frozen materials.

Water Resources

As described in Section 3.1.2.5, the primary impacts on surface waters in the Mackenzie Delta might be (1) channel erosion, (2) icings, (3) depletion of stream flow during construction, and (4) drainage disruption. Within the Mackenzie Delta Region, the Cross-Delta Route from Shingle Point to Thunder River would cross 6 major streams and about 138 minor streams (see Table 8.1.2.9-6).

As with the proposed route, the primary impact on ground water would be the disturbance of the shallow active zone overlying permafrost during pipeline construction and operation (see Figure 3.1.2.5-1b). Disturbance of the thermal regime in the shallow active layer might result in aufeis, accelerated thermal degradation, accelerated erosion, frost heaving, and possible explosive icing mounds. Another potential impact on ground water would be the influx of liquid wastes and leachate from sanitary landfills.

Vegetation

The kinds of effects the Cross-Delta Route right-of-way and facilities will have on Herbaceous Coastal Tundra, Low Shrub-Heath Tundra and Forest-Tundra communities will be identical with those previously discussed for the proposed route (Section 3.1.2.6).

From Shingle Point (Figure 8.1.2.2-1) to the Mackenzie Delta the right-of-way is essentially parallel to the Prudhoe Bay Supply Line of the proposed route and, although nearer to the Beaufort Sea coast, will cross the same patterns of cottongrass tussock and wet sedge meadow types of vegetation.

The right-of-way will occupy 407 acres (Tables 8.1.2.2-1 and 2) and other facilities 219 acres in this 28-mile segment. During construction, there will be disruption due to ditching and spoil cleanup on one-third of the right-of-way and the potential of compaction or disturbance to the moss-peat layer and vegetation of the traffic lane and work pad. Off right-of-way traffic or misuse of snow roads during winter construction, as well as overland traffic to meet summer emergencies, will produce thaw and thermokarst topography. During the operation phase, the effects will be minor although revegetation processes will be slow.

In the Low Shrub-Heath Tundra, 102 miles of right-of-way will have minor to moderate effects on 1,566 acres of vegetation (Table 8.1.2.2-1) and permanent facilities will destroy an additional 467 acres (Table 8.1.2.2-2). Seventeen miles of the Prudhoe Bay Supply Line crossing low shrub-heath communities will be dual construction, doubling the pipe length and increasing the right-of-way acreage of vegetation affected. The Richards Island Supply Line to Tununuk Junction and the Main Line from Tununuk to Noell Lake, about 30 miles south of Inuvik, affects plant communities very similar to the proposed route and previous comments apply (Section 3.1.2.6).

Right-of-way clearing will be a minor problem on any part of the Cross-Delta Route and, except in the Forest-Tundra, will involve only the removal of tall shrub communities of alder and willows usually associated with drainages. From Noell Lake to Thunder River, the pipeline will cross 102 miles of Forest-Tundra, the right-of-way affecting 1,484 acres, and permanent facilities 365 acres, of these mixed vegetation types. Over most of this segment spruce is scattered or forms open forests and little forest vegetation will be lost to clearing operations.

The effects of misuse of snow roads, cross country summer travel, fire, and drainage disruptions producing thaw and erosion, are the same as for the proposed route (Section 3.1.2.6).

The Cross-Delta Route has both positive and negative effects in comparison to the proposed route. It is 139 miles shorter than the proposed route and will have less overall effect on plant communities, especially those of the Forest-Tundra. It will have greater adverse effects on Herbaceous Coastal Tundra because of an additional 37 miles of right-of-way crossing of these vegetation types in the Mackenzie Delta, 20 miles of which is dual pipeline construction. The latter, in addition to 17 miles of dual construction in the Low Shrub-Heath Tundra, will increase actual pipeline length constructed an additional 37 miles and reduce to about 102 miles the difference in pipeline length compared to the proposed route.

Another potential adverse effect within the Mackenzie Delta is the planned summer construction of dual pipeline crossings of Shallow Bay and major stream channels. In the Mackenzie Delta, the Prudhoe Bay Supply Line will affect 635 acres of herbaceous tundra vegetation on the right-of-way

Table 8.1.2.2-1 Length and area of right-of-way of Cross-Delta Route affecting various vegetation types--Shingle Point and Richards Island to Thunder River

Vegetation	Right-of-Way (Miles)[1/]			Area of Land Use (Acres)		
	Segment Length	Pipe Length		Single	Dual[2/]	Total
		Single	Dual			
Herbaceous Coastal Tundra	65	45	40	654	388	1,042
Prudhoe Bay Supply Line	65	45	40	654	388	1,042
Coastal Plain	28	28	--	407	--	407
Mackenzie Delta	37	17	40	247	388	635
Low Shrub-Heath Tundra	102	85	34	1,236	330	1,566
Prudhoe Bay Supply Line	17	--	34	--	330	330
Richards Island Supply Line to Tununuk Junction	19	19	--	276	--	276
Main Line-Tununuk Junction to Noell Lake	51	51	--	742	--	742
Parsons Lake Lateral	15	15	--	218	--	218
Forest-Tundra	102	102	--	1,484	--	1,484
Main Line-Noell Lake to Thunder River	102	102	--	1,484	--	1,484
	S.T.	232	74			
Total	269	306		3,374	718	4,092

[1/] Mileage figures rounded to nearest whole number.

[2/] Assumes addition of 40 ft. to right-of-way for second ditch line and spoil pile.

Table 8.1.2.2-2 Estimated areas of vegetation affected by right-of-way and facilities along the Cross-Delta Route--Shingle Point and Richards Island to Thunder River

Land Use (Acres)

Vegetation	Right-of-Way	Compressor Station	Communication Tower	Airstrip	Stockpiles, Wharves & Misc. Pads	Perm. Roads	Borrow Pits[1]	Total
Herbaceous Coastal Tundra	1,042	62	17	100	95	61	40	1,417
Prudhoe Bay Supply Line	1,042	62	17	100	95	61	40	1,417
Coastal Plain	407	31	6	100	35	7	40	626
Mackenzie Delta	635	31	11	--	60	54	--	791
Low Shrub-Heath Tundra	1,566	29	23	200	66	29	120	2,033
Prudhoe Bay Supply Line	330	--	--	--	20	--	--	350
Richards Island Supply Line to Tununuk Junction	276	--	6	--	2	--	--	284
Main Line-Tununuk to Noell Lake	742	29	11	200	42	29	120	1,173
Parsons Lake Lateral	218	--	6	--	2	--	--	226
Forest-Tundra	1,484	85	39	--	30	131	80	1,849
Main Line-Noell Lake to Thunder River	1,484	85	39	--	30	131	80	1,849
Total	4,092	176	79	300	191	221	240	5,299

---

[1] Further borrow will include 340,000 cubic yards of granular fill from Shallow Bay.

and remove from production 156 acres to be occupied by permanent facilities. One stockpile area of 20 acres and 330 acres of right-of-way will affect Low Shrub-Heath Tundra.

The vegetation of the low alluvial islands of the Mackenzie Delta is not well known but appears to be sparse. There is a large component of pioneer communities characteristic of a dynamic environment of shifting streams, marked natural erosion and sedimentation, and recurring inundation. Winter construction on properly used snow roads will predictably have minor effects on terrestrial vegetation.

Snow roads as access to stockpiles and borrow pits will total 112 miles, or about 448 acres, over the Cross-Delta Route, but 60 percent of the roads, mostly in the delta, will utilize frozen stream channels and will affect only about 180 acres of vegetation.

The principal effect of construction and operation, in addition to the 5,299 acres of the right-of-way and permanent facilities, will be directly related to the protection of permafrost and the avoidance of erosion. Snow road tests at Inuvik indicate minor damage to vegetation or the insulating organic layer under heavy traffic loadings.

The greatest threat to the integrity of surfaces and underlying permafrost is summer construction at major river crossings. Disturbance to vegetation and the moss-peat layer is expected to be heavy at the sites of five major channel crossings in the Mackenzie Delta. The probability is high that all activities not confined to planned gravel work pads will not only be destructive to vegetation but will induce thaw and subsidence and continuing vegetation losses until thaw and erosive processes are brought under control.

Slope failures may result in vegetation losses at stream crossings in all seasons of construction in hilly areas of the route. After construction, such vegetation changes may be expected to be minor.

During the years of pipeline operation, air cushion vehicles will have little effect on vegetation but in the swampy terrain of the alluvial, deltaic islands low ground pressure, balloon-tired vehicles will cause extensive damage to herbaceous plant communities and compact the organic substrates. On better drained areas neither herbaceous nor woody shrub types of vegetation would be much affected by these vehicles in summer.

Stream diversions, slope failures, cut-grading, and disposal of excess spoil materials will cause heavy siltation in streams. Deltaic channels normally carry heavy suspended loads and the addition of more sediments will probably have little effect on aquatic vegetation. Continued increased siltation could interfere with phytoplankton populations in streams.

Accidental discharge of oil or toxic chemicals, such as methanol test fluid, would have major impact on plants and especially on phytoplankton. The probability of such events cannot be estimated, nor their intensity and duration.

Wildlife

The Cross-Delta Route would reduce the length of right-of-way (number of miles disturbed) 139 miles. The Richards Island and Noell Lake to Thunder River realignments would have essentially the same kinds of impacts as the proposed route, but they would be greater in number. The two most important increased impacts would be on the Richards Island grizzly bear and on waterfowl in the area near Travaillant Lake. Crossing the delta, however, would encounter species (Beluga whales) and estuarine resources not encountered with the proposed route. It would also have the same impacts on critical waterfowl and shorebird habitats across the delta and along the coastal areas to the west that the proposed route would have.

Fish

The impacts on fishery resources along the Richards Island Supply Line and Noell Lake to Thunder River would be the same as described for the proposed route.

The major differences in fishery resources would be in crossing the delta. Since the delta is an exceptionally important estuarine resource, the potential adverse impacts could be severe. The Cross-Delta Route requires 85 crossings, whereas the proposed route requires 132. Even though it requires fewer crossings, more of them are major: 17 for the Cross-Delta and 6 for the proposed route. Most of these major crossings are in the delta.

The stream gradients of the crossings in the delta are lower and consequently the water velocities are slower. This may result in more localized sedimentation problems than would be the case of the proposed route. In addition, some of the major delta crossings would be made during the summer. The Applicant believes this would minimize the impacts since many species are not there during the summer and because sediment loads are naturally high at that time of year. This may not minimize the impacts, however, as the natural sediment load may be at or near the maximum tolerance levels for some species. Any additions in sediment load caused by construction may be critical. In addition, higher summer flows would distribute sediments greater distances downstream. Insufficient information is available to determine whether summer or winter crossings would have the least adverse impact.

Mammals

Most mammals that would be encountered are similar for either route. There are, however, three significant differences: the porcupine caribou herd, grizzlies, and beluga whales.

The Cross-Delta Route would bypass caribou migration routes along the west side of the Delta.

Richards Island apparently has a greater concentration of grizzly bear than other areas in the region. The longer Cross-Delta Route on Richards Island would increase grizzly impacts.

Beluga whales using Shallow Bay during the summer would conflict with summer construction of the pipeline at the major crossing. The Applicant's studies indicate that the whales are mostly gone by the second week of August. They propose to delay construction to minimize these impacts. This would obviously reduce direct encounters; however, little information is available on why they use the area and consequently which of their annual requirements are provided in the Bay. Sedimentation and other pollution caused by pipeline construction may have an impact on the whales in unknown ways.

Birds

The most serious impact of the Cross-Delta Route would be on the critical habitats of geese and swan species in the outer delta. This is one of the important waterfowl areas on the North American Continent. Some of the larger channels would be crossed in the summer and early fall during critical seasons of rearing young, concentrated feeding prior to migration, and staging for migration. In addition, a compressor station with its continuous noise is planned in and near critical areas for some species. Periodic airplane flights during operation and maintenance would result in continuing impacts throughout the life of the project.

The remainder of the Cross-Delta Route would have similar impacts as those of the proposed route, except near Travaillant Lake where there is a more important waterfowl habitat, and thus increased impacts.

Wildlife Impact Summary

The Cross-Delta Route would have advantages over the proposed route in that it is 139 miles shorter, the Porcupine caribou herd migration along the west side of the delta would not be disturbed, and the wilderness values and fish and wildlife resources along the west edge of the 100-mile-long delta would remain undisturbed and future management options preserved.

The impacts on geese, swans, whales, and fishery resources in the outer delta, however, could be serious. Information on these species and their impacted habitats is not adequate to predict the seriousness of the impacts. Detailed studies are needed to develop adequate information to enable predicting impacts with reasonable certainty. It is vital that this be done because the impact on geese and swan species is potentially catastrophic.

Relocating the route to the south a few miles may move it out of critical geese and swan habitats. Changing the compressor station location could also eliminate serious impacts.

The Cross-Delta Route has the potential of eliminating many impacts. Further studies may indicate that adverse impacts could be minimized or eliminated by route realignments; such studies should be given serious consideration from the standpoint of fish and wildlife resources.

Ecological Considerations

The general nature of impacts on ecosystems has been discussed for the proposed route (Section 3.1.2.8) and all comments apply to the Cross-Delta Route. Specific effects are the same for those ecosystems that are affected in common; namely, Inner Continental Shelf Marine, Ice-Affected Coast, Low Shrub-Heath Tundra, Herbaceous Coastal Tundra, Forest-Tundra, and Freshwater Riverine and Lake systems.

The Cross-Delta Route introduces no change in the kinds or degree of adverse effects but has the positive effect of reducing by about 100 miles the amount of pipeline that would affect ecosystems. Most of this reduced effect will apply to the Forest-Tundra. The Prudhoe Bay Supply Line will lie nearer to the Beaufort Sea and pose a greater threat to important coastal bird populations. Further, the revised alinement increases the probability of adverse effects on lakes that are important nesting and feeding areas of waterfowl.

The Richards Island Supply Line from the Mackenzie Delta will have the same effects as the proposed route, and these include potentially critical disruptions to some of the most sensitive ecosystems of the entire pipeline project. The greatest threat will be to the bird and mammal components of the ecosystems.

The Main Line from Tununuk Junction to Thunder River will have consequences equivalent to the proposed route, but will traverse somewhat less of the Forest-Tundra and will apparently encroach upon more critical fish and wildlife habitat in the Travaillant Lake and Travaillant River regions.

The new ecological dimension introduced by the Cross-Delta Route is the direct invasion of the low alluvial islands and waterways of the modern deltaic environment. The ecosystems of the modern delta are not well enough known on a component-by-component basis, much less as integrated systems, to permit evaluation of the effects of construction and operation of a pipeline.

It may be assumed that the aquatic and terrestrial systems are no more sensitive to change than equivalent systems in the geologically older and ecologically more mature parts of the delta, such as Richards Island. They may, in fact, be less sensitive in terms of changes induced by erosion and deposition processes, since rapidly fluctuating changes of this type are characteristic of this environment. The communities are predominantly early pioneer stages of ecosystem development and the organisms are adapted to the highly dynamic environment.

The critical aspect of construction across the delta is attributable to the timing of activities; the engineering solutions to transportation and to water crossings; the requirement for dual pipelines to give greater assurance of uninterrupted gas flow; and a direct intrusion into estuarine and marine environments.

Planned winter construction for the crossing of all land surfaces and most waterways poses no new problems, and ecosystem protection depends upon the efficacy of snow roads and the control of erosion, especially at river crossings. Winter crossings of larger streams deep enough not to freeze to bottom will impose a siltation threat on what are believed to be significant overwintering fish populations. This threat would be compounded by any accidental discharge of toxic chemicals or organic waste which would contribute to oxygen depletion.

Planned summer construction of dual pipelines across Shallow Bay and larger streams will entail major erosion and siltation effects on both streams and marine environments. More importantly, the disturbance effects of human presence, aircraft, construction machinery, river traffic, and marine transport will occur during critical nesting, molting, feeding, and staging periods of large populations of migratory waterfowl, and of the summer residence of beluga whales in Shallow Bay.

There is no timing of summer construction that will at once avoid impact on spawning or migrating fishes, whales, and either early summer or autumn activities of birds. The existing state of knowledge does not permit prediction of the probable short-term effects of summer construction.

Dual pipeline construction per se will have little effect beyond the relatively small increase in area of right-of-way, but it is indicative of concern for pipeline integrity in the delta environment. The probable incidence of pipeline rupture and the necessity of emergency repairs during the operational years of the pipeline cannot be predicted. Repair operations during the summer season, entailing the use of self-propelled air cushion vehicles, or helicopter-towed air cushion-assisted vehicles, would be highly disruptive to bird and mammal populations. Balloon-tired, low ground-pressure vehicles on land would add another increment of noise disturbance to wildlife and be damaging to the aquatic and semiaquatic communities of the low swampy terrain.

The entire Mackenzie Delta, considered as a single ecosystem with freshwater, marine, and terrestrial components, is one of the most biologically productive systems of northern Canada. High levels of productivity are most evident in the conspicuous and well-known large populations of waterfowl, aquatic and upland furbearers, large game predators such as polar, grizzly, and black bears, and large grazing ungulates such as caribou and moose.

These vast renewable resources were long the subsistence base for Native man living successfully as an integral part of the ecosystem. In modern times, to the present, this resource base has remained viable and still provides total subsistence to some Natives who choose this life style, partial subsistence to many others, and a source of cash income to still others.

The existence of ecosystems with such a wealth and diversity of fishes, birds, and mammals is evidence of high productivity at all trophic levels of the food web. It is equally evident that other ecosystem conditions of living and reproducing are in balance under the existing climate.

There is no apparent threat to primary production or to the productivity of consumer populations at the lower trophic levels of the terrestrial systems. At similar levels among aquatic systems there is a greater potential for deleterious effects of catastrophic or chronic, accidental discharge of toxic chemicals. The proposed project probably would have relatively minor effects of this type, but every occurrence would add to the cumulative effects of a number of other related human activities and projects.

The greatest threat to the integrity of the Mackenzie Delta ecosystem will most probably be the continuing disturbances to behavior patterns and breeding success of birds and mammals. The toll taken by the proposed pipeline may ultimately be relatively minor but its effects cannot be taken in isolation. The pipeline is part of a system of exploration for fossil energy sources, the production of these resources when discovered, the gathering of gas and oil through networks of pipeline systems, and delivery of these fuels to markets. Expansion of these activities in the Mackenzie Delta, along the arctic coast, and offshore on the Continental Shelf appears to be a certainty. These directly related activities which are dependent upon pipelines or other means of transport, as well as other indirectly related human activities which will follow, can only be predicted to be critical long-term, cumulative threats to vulnerable ecosystems.

Social and Economic

A change from the proposed route to the Cross-Delta Route would be of very minor overall consequence to the social and economic conditions that have been described for the proposed route. The impact would reduce the project cost by a relatively small, but significant, amount because the Cross-Delta Route is about 139 miles shorter and it avoids some difficult construction terrain and two major and costly river crossings. Any immediate impacts on socio-economic conditions would be limited to the Mackenzie Delta subregion, and would be essentially related to changes in the distance of the pipeline from the communities of Aklavik, Fort McPherson, Arctic Red River, and Inuvik.

The proposed route lies about 12 miles from Aklavik and Inuvik, and 6 to 8 miles from Fort McPherson and Arctic Red River. The Cross-Delta Route would place the line approximately 50 miles from Aklavik, 80 miles from Fort McPherson, 56 miles from Arctic Red River, and 16 miles from Inuvik. The substantially greater distances from the first 3 communities would greatly reduce any undesirable impacts on these small communities that possibly might result from being within 6 to 12 miles of the active construction sites. The distances of 50 to 80 miles, however, would probably eliminate many economic opportunities that might be available if construction activities were only a short distance away. The change of only about 4 miles greater distance from Inuvik, a relatively large and structured community, should not be of any consequence, as Inuvik would be a base for construction and operations for either route.

In terms of employment of local residents of the 3 small communities, some differences in impacts might result depending upon the individuals' attitudes toward going slightly farther from home to take jobs. Inasmuch as the construction work would be transitory, some temporary movement of workers from their home communities is presumed in any case.

A significant negative socio-economic impact conceivably could result in Aklavik, Fort McPherson and Arctic Red River because their greater distance from the Cross-Delta Route pipeline might make construction of spur lines to supply them with gas fuel economically impractical. The added distance of only 4 miles from Inuvik would probably not be a significant economic deterrent to construction of a branch gas-service line.

Paleontological, Archeological, Historical

In the Mackenzie Delta, few archeological, paleontological or historic sites are known and because the area is subject to seasonal flooding, erosion, and deposition, it is unlikely that any major archeological resources would be located along the route. However, all phases of construction involving land use could possibly cause loss of, or damage to, archeological and historical resources. Previously unknown archeological, paleontological, or historic sites might be discovered as a result of construction activities and protected provided proper mitigating measures were undertaken.

Recreation and Esthetic Resources

Although recreation resources along the Cross-Delta Route are almost completely undeveloped, pipeline construction and operation could adversely affect some potential recreation areas. The coastal portion of the route would become less of a wilderness area because of the presence of men to maintain the proposed pipeline and compressor stations. Because fish and wildlife populations are a major part of the recreation resources of the area, any adverse impact on them would also be an adverse impact on recreation. The one compressor station proposed for location on the delta is near an area of important waterfowl habitat. Noell Lake and the smaller lakes in the Travaillant Lake area could be subjected to overfishing by pipeline workers. Those lakes are presently used by residents of Inuvik and Arctic Red River.

West of the Mackenzie Delta, the proposed pipeline, when viewed from the air, would appear as a heavily disturbed seismic line for 3 to 5 years following construction, and possibly longer. The delta region itself has been subject to much seismic exploration, resulting in a grid pattern of seismic lines spaced 1 to 3 miles apart. As the pipeline right-of-way would appear similar to a wide seismic line, the impact on aerial viewing would not be severe. To a ground-level observer, the cleared right-of-way would not be obvious due to the general flatness of the area.

8.1.2.3 Babbage Bight Corridor and LNG Export Terminal Site

The Applicant has considered, as part of an alternative transportation system, the construction of a liquified natural gas (LNG) marine export terminal at Babbage Bight, Yukon Territory (CAGPL, 1974e, 2.8 and 2.9), which is approximately 70 miles southeast of the Alaska-Yukon border on the coast of the Beaufort Sea. Apparently, Babbage Bight is one of the few sites along the coast of the Beaufort Sea between Prudhoe Bay, Alaska, and Cape Bathhurst, N.W.T., that could be considered for a terminal site; most of the waters along this part of the coast are extremely shallow. Both ice-breaker tankers and giant cargo submarines have been considered as potential means of transporting LNG to market in the conterminous United States. In order to transmit gas to the LNG plant at Babbage Bight, 48-inch diameter pipeline segments with related compressor stations and appurtenances would have to be constructed from Prudhoe Bay and Richards Island. The Applicant has not provided information about the exact location of this alternative corridor nor of the LNG plant and terminal facility; therefore only general comments can be made about the existing environment and the potential environmental impacts of these facilities. Environmental impacts of LNG transshipment are described in the Alternatives volume.

A possible location for the Babbage Bight Corridor is shown on Figure 8.1.2-1. It would consist of: 1) a Prudhoe Bay Supply Line coincident with the proposed route from the Alaska-Yukon border to about Milepost 291; 2) a Richards Island Supply Line (including a Parsons Lake Lateral) coincident with parts of the Cross-Delta Route, as far west as Milepost 291; and 3) a 15-mile lateral line to the LNG export terminal near Babbage Bight. (The exact configuration of routes has not been determined.)

Description of the Existing Environment

Climate

The coastal Arctic climate of the Babbage Bight region is the same as that of the northern part of the proposed route (Section 2.1.2.1). Mean daily temperatures vary from a January low of -20° to -25° F, to a July high of 50° to 55° F. From 250 to 275 days have daily temperatures below 32° F. Total precipitation is about 7.5 inches per year, most of which falls as rain during the summer. Snowfall is 20 to 30 inches annually; some snow may be expected in all months. In winter, extreme high winds may reach 60 mph, but generally do not exceed 40 to 45 mph during the rest of the year.

Topography

The Babbage Bight Corridor would coincide with the northernmost parts of the proposed and Cross-Delta routes in Canada (Sections 2.1.2.2 and 8.1.2.2).

Geology

Most of the Babbage Bight Corridor would coincide with the northernmost parts of the proposed route and the Cross-Delta Route. Near Babbage Bight, the corridor would cross the flat to gently rolling, coastal plain, which is underlain by ice-rich gravelly silt (till), organic-rich deposits, and locally, sandy gravel. Presumably an attempt would be made to locate the marine export terminal on sand and/or gravel deposits; however, the Applicant does not give the location of the terminal site.

Active coastal processes in the Babbage Bight area have been described by Lewis (1975). Portions of Kay Point, which encloses Babbage Bight to the east, have retreated 25 to 90 meters during the last 16 to 18 years owing to vigorous coastal erosion and to thawing of massive ground ice. Much of the eroded sediment has been deposited on Kay spit, at the tip of the point, which has extended 400 meters westward since 1952. Sedimentation probably is active also in Babbage Bight, a flat-bottomed estuary with water depths of only 1 to 2 meters. Although tidal range in this region is only 0.7 meter, storm surges can raise sea level several meters and completely inundate Kay spit. Hydrologic features and permafrost conditions along the Babbage Bight Corridor are shown in Tables 8.1.2.9-8 and 9. For a description of other aspects of the geology along the Babbage Bight Corridor see Sections 2.1.2.3 and 8.1.2.2.

Mineral Resources

Other than construction materials, no mineral resources are known in the area of the Babbage Bight Corridor and LNG Export Terminal Site.

Water Resources

The Babbage Bight Corridor lies entirely within the Arctic Coastal Region. Streamflow data are inadequate to determine meaningful flow magnitude and variability relations. Floods can occur as the result of snowmelt runoff and can be aggravated by ice jams. Summer rainstorms cause more floods on streams west of the Mackenzie River than on the east side. Stream crossings along the Babbage Bight Corridor are summarized in Table 8.1.2.9-8.

For a description of other aspects of water resources along the Babbage Bight Corridor, see Sections 2.1.2.5 and 8.1.2.2.

Vegetation

The vegetation traversed from Richards Island would include Low Shrub-Heath Tundra, and Herbaceous Coastal Tundra (Environment Protection Board, 1974, Vol. III; Hernandez, 1974). The Prudhoe Bay Supply Line and the area around Babbage Bight would cross Herbaceous Coastal Tundra. Details of the communities of these zones are discussed for the proposed route in Section 2.1.2.6.

Wildlife

Although the exact locations of the pipeline and processing facilities are not cited, they would occur in the same general area, over the same type of terrain, and affect the same fishery resources, birds and mammals as described for northern portions of the proposed route (Section 2.1.3.7).

Ecological Considerations

The major ecosystems affected include the Marine Inner Continental Shelf, Marine Ice Affected Coast, Freshwater Lake and Riverine, Herbaceous Coastal Tundra, Low Shrub-Heath Tundra, and Forest-Tundra. The general relationships of ecosystems and the specific relationships of ecosystems that are in common with the proposed route have been previously discussed (Sections 2.1.2.8 and 3.1.2.8) and are applicable to the Babbage Bight Corridor.

Also applicable, with respect to the marine ecosystems, are the discussions of the Cross-Delta Route (Section 8.1.2.3) and of the Offshore Corridor alternative (Alaska volume of the Environmental Statement, Section 8.1.1.1).

Economic Factors

The economic factors that would be pertinent to the Babbage Bight Corridor are the same as those described for the proposed and Cross-Delta routes between the Alaska-Yukon border and the Mackenzie Delta region (see Sections 2.1.2.9 and 8.1.2.2).

Sociological Factors

Sociological factors applicable to the Babbage Bight Corridor are the same as those given for the northern portion of the proposed and Cross-Delta routes. The coastal area of Yukon Territory, between the Alaska-Yukon border and the Mackenzie River, is uninhabited, but is visited occasionally by residents of the region for hunting, fishing and whaling. This situation would be expected to continue in the absence of the proposed project (see Sections 2.1.2.10 and 8.1.2.2).

Land Use

Descriptions of land use in the discussion of the northern part of the proposed and Cross-Delta routes (Sections 2.1.2.11 and 8.1.2.2) are applicable to the Babbage Bight Corridor and LNG Export Terminal Site.

Archeological and Historic Values

Among the known archeological and historic sites along the Babbage Bight Corridor are the following: Firth River Valley, Babbage River, and the east branch of the Mackenzie River, near its mouth. A number of potential archeological sites have been identified by Millar (1974) along the segments of the proposed route with which this corridor coincides.

Early man probably did not inhabit the Arctic coastal area until grasslands spread northward with the post-Pleistocene climatic change. Descendants of the earlier megafauna hunters probably followed the grassland habitat and the fauna it supported north into the Arctic drainage and possibly the Arctic littoral areas. About 4,000 years ago, the earliest ancestral Eskimos moved rapidly eastward along the coast from the Bering Strait region as far as Labrador and Greenland. They combined seasonal caribou hunting with some exploitation of the marine resources.

Recreation and Esthetic Resources

While there are no official recreation facilities or areas along the corridor, the region has potential recreation value as a unique wilderness area. Such outdoor recreational activities as photography and nature study, hunting, fishing, hiking, backpacking, and whitewater boating could take place here in an uncrowded and scenic environment. Certain drawbacks such as remoteness from population centers, lack of services, and short season would tend to limit the use and value of the region as a recreation resource for some, while adding to its attractiveness for those who really want to "get away from it all."

Near the Yukon-Alaska border, the major landscape features are the peaks of the British Mountains to the south, with alluvial fans along the break in slope, and the Beaufort Sea to the north. The low-profile vegetation includes dwarf shrubs, herbaceous plants, and lichen-moss ground cover. Farther east, the scenery consists of smooth, rolling topography down to the sea, with similar low-profile vegetation. Farther east, the Mackenzie Delta provides a landscape of low relief with mostly low-profile vegetation and scattered stands of conifers.

Air Quality

No data on air quality are available for the region of the Babbage Bight Corridor and LNG Export Terminal Site, but there is no reason to expect appreciable pollution as no potential sources are in the area.

Environmental Noise

The general discussion of environmental noise along the proposed and Cross-Delta routes (see Section 2.1.2.15) is also applicable to the Babbage Bight Corridor. Ambient sound levels along this corridor are extremely low.

Evaluation of the Environmental Impacts

Climate

Construction of a gas pipeline and a LNG terminal in the Babbage Bight Corridor would cause local introduction into the atmosphere of particulate and gaseous (including water) emissions from the internal combustion engines of construction equipment. This could cause ice fog during calm, cold periods of the winter months, but would have no impact on regional climate. Dense ice fogs formed at airstrips and heliports would interrupt operations, usually for periods of several hours but exceptionally for as much as a day. Advection fog in summer, often lasting for several days, would critically affect the reliability and safety of aircraft operations.

Drifting pack ice in the Beaufort Sea would be a continuing threat to wharves, jetties and other shore installations, as well as to surface shipping. Bottom-scour by grounded ice would be a hazard to any pipelines which might be used for purposes of offshore loading of LNG to ships. Pipe or ship rupture resulting from ice impacts would be an apparent threat to human life and to the marine ecosystem.

Topography, Geology, and Soils

The potential impacts on the topography, geology, and soils that would be caused by the construction of a pipeline along the Babbage Bight Corridor and by the construction of a marine export terminal at Babbage Bight would be similar in type and degree to those affecting the proposed route (Section 3.1.2.2) and the Cross-Delta Route (Section 8.1.2.2).

Coastal hazards to a pipeline and LNG terminal facilities in the Babbage Bight area include (1) vigorous coastal erosion, (2) rapid sedimentation on Kay spit and probably in Babbage estuary, (3) storm surges across Kay spit, and (4) sea ice that, in some years, may remain along the coast virtually throughout the summer (Lewis, 1975).

Mineral Resources

Construction materials would be irretrievably committed if the Babbage Bight Corridor and LNG Export Terminal Site were selected for a gas pipeline and ancillary facilities. There are no other known mineral resources in this area.

Water Resources

Construction of the pipeline and LNG terminal in the Babbage Bight Corridor could alter the surface-water environment. The degree of potential impact would depend upon the design and the measures taken during construction to minimize the impact. For an evaluation of the environmental impacts see Section 3.1.2.5.

Vegetation

The use of land for facilities, and therefore the removal of vegetation, would be identical to those of the proposed route and the Cross-Delta Route, with the addition of 200 acres for an LNG plant at Babbage Bight (CAGPL, 1974e, 2.8.2, p. 56). The potential impact of the operation of an LNG plant on vegetation should be further investigated, if this corridor is chosen.

Wildlife

Since the entire Babbage Bight Corridor is in the general vicinity of the proposed and Cross-Delta routes, the impacts on fish and wildlife resources discussed in Sections 3.1.2.7 and 8.1.2.2 are applicable. The installation of a liquefaction plant would increase and compound the potential for conflicts with land birds and mammals, and freshwater fishery resources. Also, the requirement for offshore pipes and terminals and onshore facilities would add a new dimension to the threat of adverse impacts on marine fish, sea mammals and birds. Marine mammals and fish, and birds that frequent the marine environment would certainly be adversely affected by any spills of fuel oil that might occur. The installation and maintenance of a liquefaction plant and loading terminals presumes an influx of permanent human population which in itself would substantially increase the stress upon the fragile, coastal biotic communities.

Ecological Considerations

The nature of impact on ecosystems has been treated for the proposed route (Section 3.1.2.8) and the discussion generally is applicable to the Babbage Bight Corridor.

Economic Factors

Use of the Babbage Bight Corridor for the proposed project would introduce significantly different and new economic developments in the presently uninhabited coastal region of Yukon Territory. A liquefied natural gas (LNG) plant would be required onshore at Babbage Bight, and an offshore loading facility for either tankers or submarines. Service and transportation facilities and a permanent townsite of substantial size with related activities might also be needed. This type of LNG installation would result in a higher degree of concentration of human and industrial activities in one place than would be created by pipelines along any of the other routes or corridors.

No detailed projections are given of the level and types of activities, employment, income, and tax base that this project would generate. Presumably the town that would be established during the construction phase could be sustained, possibly on a slightly reduced level, by the continuing requirement for an operational and maintenance staff for the pipeline, LNG plant, and offshore loading facility.

Sociological Factors

There is no permanent population in the immediate area of Babbage Bight or along the entire Yukon Territory coast. If the LNG installation were made, both permanent and temporary population would be expected in this area, and probably a significant number of the people might migrate to this center from communities such as Inuvik, Aklavik, Arctic Red River, Fort McPherson, and Old Crow. No indication is given of the number of people that would be required in primary employment, or in supporting activities.

Initially a great amount of planning and employment would be required to construct housing, commercial buildings, a school, gas-related plants, transportation facilities, water and sewer systems, etc. The establishment of local government would be essential. Proper measures would be required to avoid objectionable noise levels in the local area.

Land Use

The Babbage Bight Corridor and LNG Export Terminal Site have no permanent residents and comprise essentially unused land with no uniquely valuable social or economic attributes. If this corridor were selected, the construction and operation of pipelines and related facilities would probably have no impacts on the use of land not exclusively dedicated to pipeline right-of-way and ancillary facilities, including borrow sites.

Archeological and Historic Values

Construction of the proposed project and related activities could cause loss of, or damage to, the archeological resources of the region, particularly at sites of high archeological potential such as river crossings, eskers, and inactive flood plains. If proper salvage measures were undertaken, damage to archeological sites could be minimized.

Recreation and Esthetic Resources

Because there are no existing recreation facilities such as provincial parks, campsites, or private resorts along the Babbage Bight Corridor, construction of the project would have impact only on potential recreation areas and resources. The LNG plant, service, and transportation facilities, and permanent townsite would have a significant impact on the wildlife of the area and thereby severely reduce recreational potential whether in the form of hunting or observation. Impact on sport fishing might mainly come from increased fishing pressure by employees of the project, especially in the Mackenzie Delta area, where many of the good fishing lakes are presently used by residents of Inuvik and Arctic Red River.

A pipeline and LNG plant within the Babbage Bight Corridor would eliminate the coastal region as a quasiwilderness area. The pipeline right-of-way would appear from the air as a heavily disturbed linear feature, and probably would remain visible for decades. From ground level, such auxilliary construction features as compressor stations and borrow pits would spoil vistas and general scenery, although visual impact would be less in the Mackenzie Delta area because it is already crisscrossed by seismic lines.

Air Quality

Construction of a gas pipeline and LNG terminal in the Babbage Bight Corridor would cause local introduction into the atmosphere of particulate and gaseous (including water) pollutants from the internal combustion engines of construction equipment. A combination of dryness, wind, and construction activity would give rise to small dust clouds. Operation of facilities in this corridor would involve minor pollution plumes from stationary equipment and some pollution from mobile equipment. All pollutants, however, would probably be rapidly dissipated.

Environmental Noise

Noise impacts along the Babbage Bight Corridor would be essentially the same as those of the proposed and Cross-Delta routes. These impacts are discussed in Section 3.1.2.15. The LNG export terminal would probably add an additional component of noise impact at the site but levels of sound that would be produced are not known.

8.1.2.4 Fort Yukon Corridor

The Fort Yukon Corridor (Figure 8.1.2.-1) is an alternative to the proposed route that extends from the Alaska-Yukon border (near where the Yukon River crosses the border) and Richards Island to Milepost 1265 (near Windfall, Alberta); only this part of the Fort Yukon Corridor is discussed in this section. South of this point and the first 87 miles of the Richards Island Supply Line (from Richards Island to Campbell Lake) the Fort Yukon Corridor coincides with the proposed route (Section 2.1.2, this Statement). The Fort Yukon Corridor is described in the following segments: (1) Alaska-Yukon border to North Klondike River, 87 miles (junction with Richards Island Supply Line); (2) Campbell Lake to North Klondike River, 310 miles (Richards Island Supply Line); (3) North Klondike River to Pelly Crossing, 111 miles; (4) Pelly Crossing to Watson Lake, 319 miles; and (5) Watson Lake to Windfall, 685 miles. Some of these segments are further broken down for ease of description.

Description of the Existing Environment

Climate

The climate of the area traversed by the Fort Yukon Corridor is generally similar to that of the proposed route (Section 2.1.2.1) in the same latitude range, although temperature extremes are somewhat greater in western Yukon Territory than in the Mackenzie Valley.

Topography

The topography along the Fort Yukon Corridor is described in the following geologic section under physiography.

Geology

The topography along the Canadian segment of the Fort Yukon Corridor (Figures 8.1.2.4-1, 2, and 3) is shown on a series of topographic maps published by the Canadian Department of Mines and Technical Survey at a scale of 1:250,000 (Figure 8.1.2.4-4); most of these have contour intervals of 500 feet, but a few of the maps of areas in British Columbia and Alberta have contour intervals of 100 or 200 feet. Geologic maps published by the Geological Survey of Canada at a scale of 1:250,000 cover all segments of the Fort Yukon Corridor that lie within Yukon Territory and about half of the segments in British Columbia and Alberta (Figure 8.1.2.4-5). Additional information is provided by a report on the glacial geology of Yukon Territory south of 65° N. latitude (Hughes and others, 1969), a report on the Quaternary geology of southern and central Yukon (Hughes and others, 1972), and a general description of the geology of Canada (Douglas, 1970).

Physiography

Some general characteristics of the terrain including slope categories, mountain crossings, and stream crossings are summarized in Tables 8.1.2.9-10 and 11. About 298 miles of the Fort Yukon Corridor, north of Windfall, Alberta, passes through wilderness areas more than 10 miles from any existing railway, pipeline, airfield, or settlement. There are 1,178 miles of the Fort Yukon Corridor that follow existing highways fairly closely.

Alaska-Yukon Boundary to Klondike River--This segment of the corridor follows the north bank of the Yukon River for about 75 miles to a point near Dawson and then extends up the Klondike River 15 miles to the mouth of the North Klondike. The corridor lies within the Tintina Trench, a straight, fault-bounded valley about 15 miles wide.

The westernmost 75 miles is relatively rugged, crossing several large and deeply incised northern tributaries to the Yukon River at altitudes of about 1,000 feet and climbing to altitudes of more than 2,000 feet in the divides. The North Klondike Valley section passes over gently rolling terrain with a relief of only a few hundred feet. Steep slopes that bound the north edge of the Tintina Trench lead within a few miles to peaks on the Ogilvie Mountains as high as 4,800 to 6,500 feet.

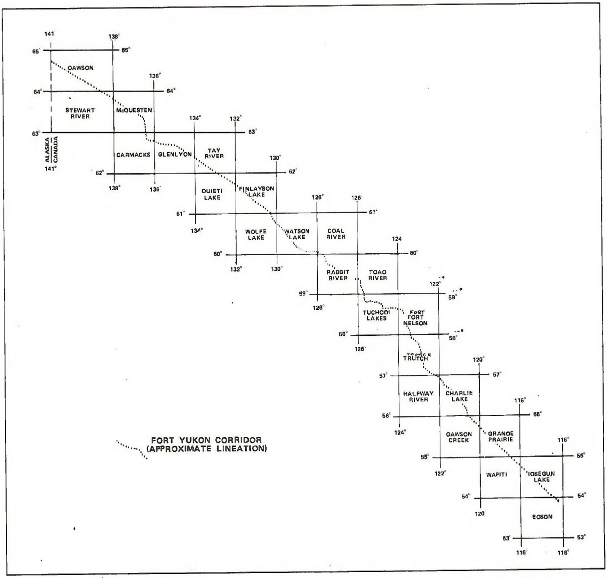


Figure 8.1.2.4-4 Index map showing topographic quadrangles crossed by the Fort Yukon Corridor

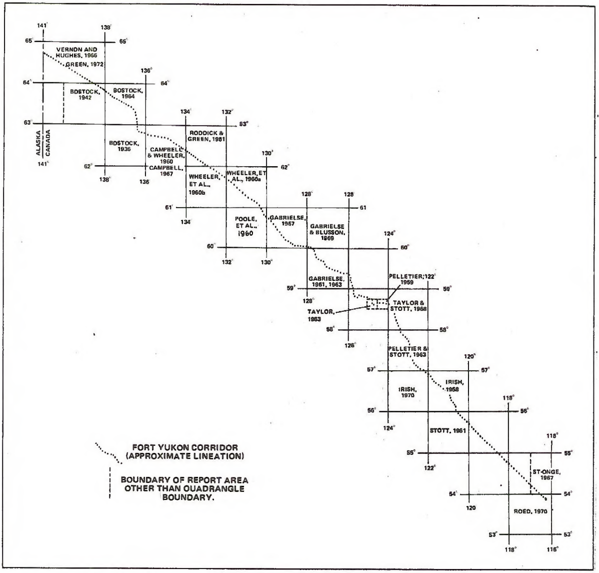


Figure 8.1.2.4-5 Index map of geological reports bearing on the route of the Fort Yukon Corridor

Richards Island to Campbell Lake--This part of the Richards Island Supply Line coincides with a portion of the proposed route. Its physiography is discussed in Section 2.1.2.3.

Campbell Lake to Mouth of North Klondike River--From Campbell Lake southwest to the Richardson Mountains, the supply line from Richards Island would skirt the Mackenzie Delta and follow the higher ground of the Anderson Plain, the Peel Plain, and the Peel Plateau (Figure 8.1.2.4-2 and Table 8.1.2.5-1). The Anderson Plain, which lies east of the Mackenzie Delta between Inuvik and Arctic Red River, is an undulating, drift-covered lowland with altitudes below 500 feet. Bedrock is exposed in some of its higher areas, 10 miles or more east of the supply line. The corridor crosses many small streams that flow westward into the Mackenzie Delta.

The corridor crosses the Mackenzie River at Arctic Red River, then enters the narrow northern tip of the Peel Plain (Bostock, 1970). The plain is a nearly level surface 300 to 400 feet above sea level. It is largely drift covered and contains many small lakes. The corridor crosses Peel River at Fort McPherson.

The east edge of the Peel Plateau is an abrupt escarpment which rises at least 500 feet from the edge of the Peel Plain. Bedrock is exposed fairly extensively across the nearly flat surface of the plateau, although it is covered by glacial drift in many areas. The western limit reached by the Laurentide ice sheet is near the west edge of the plateau. Beyond this limit, the supply line would enter the extensive unglaciated terrain of northern Yukon Territory.

The corridor for the supply line crosses the Richardson Mountains at a point where they are low and narrow relative to the higher and more rugged uplands farther to the north and south. The mountain segment traversed by the corridor appears to consist of relatively gentle slopes, rounded in profile, with low passes at about 2,000 to 2,500 feet altitude.

West of the Richardson Mountains, the corridor extends southward across the Eagle Plain, a subdivision of the Porcupine Plateau, following a series of connected ridges at altitudes of between 2,000 and 3,000 feet which form the divide between the north-trending Porcupine drainage and the east-trending Peel River system. The divide area is relatively well drained, and stands above much flatter and wetter terrain to the north and east. No major river crossings occur along this segment of the corridor.

Entering the Ogilvie Mountains, the supply line would cross a low (3,000 to 4,000-foot-high) divide to the valley of Blackstone River. This part of the route crosses unglaciated terrain of moderate relief. Rounded peaks rise to maximum altitudes of about 5,000 feet here, and are generally only 2,000 to 3,000 feet above the valley bottoms. Farther south, the corridor ascends Blackstone Valley for nearly 40 miles, crosses North Klondike Pass at an altitude of about 4,000 feet and follows the North Klondike River down to the Tintina Trench. About 25 miles north of the pass, the corridor enters the higher and more rugged glaciated parts of the Ogilvie Mountains. Peaks rise to altitudes of about 7,000 feet near North Klondike Pass; local relief across the deep glacial valleys to the north and south is 3,000 to 4,000 feet. Uplands have been intensely dissected by cirques, creating precipitous slopes and jagged ridges.

North Klondike River to Stewart Crossing--After crossing the North Klondike River, the corridor continues to follow the Tintina Trench for about 75 miles southeastward through a straight, broad, open lowland 8 to 15 miles wide, adjoined by discontinuous escarpments more than 1,000 feet high to north and south. The floor of the trench has an undulating relief of a few hundred feet for about 40 miles east of the North Klondike River. Beyond that point, the trench is occupied for some 30 miles by the entrenched valley of the Stewart River, a large and swift stream which the corridor must cross.

Stewart Crossing to Pelly Crossing--The corridor turns southward for 40 miles, crossing a low divide (an ancient glacial moraine) at the south edge of the Tintina Trench and following the broad, open lowland occupied by Willow Creek to the Pelly River. Local relief is only 100 or 200 feet, but is more sharply hummocky than in the portions of the Tintina Trench to the northwest.

Pelly Crossing to Harvey Creek--The corridor turns eastward, follows the Pelly River to the mouth of Granite Canyon, continues eastward up the broad valley of Needlerock Creek, and crosses a low divide and then extends across hummocky lowlands in the drainage basin of the Tummel River until it re-enters the Tintina Trench and rejoins the Pelly River near the mouth of Harvey Creek, 59 miles east of Pelly Crossing. The Fort Yukon Corridor enters the limits of the last continental glaciation at Pelly Crossing and remains in young glaciated terrain throughout the remainder of the route in Yukon Territory, British Columbia, and Alberta.

A hummocky glacial moraine is crossed at Pelly Crossing. For the next 8 miles eastward the corridor crosses a smooth flat glacial outwash plain. From the mouth of Needlerock Creek to the Tintina Trench, the corridor follows the grain of smooth, rounded drumlinoid topography in which local relief consists of undulating hills less than 100 feet high.

Harvey Creek to Black River--The Fort Yukon Corridor follows the Tintina Trench for 166 miles to the southeastern terminus of the trench in the Simpson Range. This segment of the Tintina Trench is 4 to 5 miles wide as it cuts through the Yukon Plateau, but it narrows to less than a mile in the Simpson Range. The general level of the floor rises from less than 2,000 feet at Harvey Creek to more than 4,000 feet at the head of the Black River. Straight but discontinuous escarpments rise on either side to hilltops that stand more than 1,000 feet above the Tintina Trench in the Yukon Plateau and to mountains that stand 2,000 to 3,000 feet higher in the Simpson Range.

The Pelly River flows in the Tintina Trench between Harvey Creek and Hoole Canyon near the west end of the Simpson Range. Beyond Hoole Canyon, the trench is occupied by the Hoole River west of the divide and by the Black River, a tributary of the Liard, on the east side. The Pelly River must be crossed at least once. Away from the river, the floor of the trench is occupied by smooth drumlin ridges and intervening depressions that extend parallel to the axis of the trench.

Black River to Watson Lake--The Fort Yukon Corridor leaves the southeastern end of the Tintina Trench, following the straight, mile-wide valley of the Black River southward into the Liard Plain and thence 80 miles southeastward to Watson Lake where it joins the Fairbanks Corridor. The Liard Plain lies at altitudes between 2,000 and 3,000 feet and has a local relief generally less than 100 feet, consisting of drumlinoid ridges and intervening depressions. The Liard River and its major tributaries are incised into canyons and steep-walled valleys several hundred feet below the plain.

Watson Lake to Windfall, Alberta--The Fort Yukon and Fairbanks Corridors join and continue across the Liard Plain, following the entrenched valley of the Liard River to Liard Hot Springs. The corridor then turns southward and crosses the Liard River and then winds for about 85 miles through the extremely rugged terrain of the glaciated Muskwa Ranges which form the northeasternmost part of the Rocky Mountains. Topography within the Muskwa Ranges is characterized by steep, rocky slopes and cliffs and by hummocky valley floors.

Emerging from the Rocky Mountain foothills, the route enters the Alberta Plateau. It first turns south and follows the broad, open valley of the Muskwa River for 70 miles, then turns southeastward and crosses a low divide into the valley of the Prophet River and crosses the Alaska Highway near highway Milepost 210. The Fort Yukon Corridor then extends southeastward for 150 miles along the crest of a broad, high interfluve between the drainage of the Beaton River to the east and the Peace River to the west.

At Fort St. John, the corridor crosses the deeply incised canyon of the Peace River and continues southeastward, mostly through the Fort St. John Lowland, for some 240 miles to the junction with the proposed route near Windfall, Alberta. This segment of the route lies in rolling country crossed at wide intervals by deeply incised streams such as the Wapiti, Athabasca, and Smoky Rivers.

Bedrock, Surficial Deposits, Permafrost, and Mass Wasting

Alaska-Yukon Boundary to North Klondike River--Bedrock within this part of the Tintina Trench consists of weakly lithified sandstone, conglomerate, and mudstone of Cretaceous or early Tertiary age. River bottoms are underlain by surficial alluvium several tens of feet thick. Steep slopes are mantled by stony colluvium. Interfluves are covered with alluvial quartz gravel as much as several hundred feet thick. Ancient, weathered glacial deposits may be encountered above the alluvium in some places on the interfluves. These ancient interfluve deposits are covered, in turn, by wind-blown silt and locally by peat having a combined thickness of as much as 30 feet (Hughes and others, 1972).

The Alaska-Yukon boundary to North Klondike River segment of the corridor is in the zone of widespread but discontinuous permafrost (Table 8.1.2.9-11). South-facing slopes and river channels are underlain by thawed ground, but flat surfaces and north-facing slopes have permafrost locally reaching thicknesses in excess of 200 feet. Ice-rich permafrost is present where wind-blown silt and peat have accumulated to substantial thicknesses. Open-system pingos are common in the region (Hughes, 1969), testifying to the fact that ground-water circulation is controlled by the distribution of permafrost and that in places the ground water is confined under hydrostatic head beneath the permafrost.

Mass wasting due to solifluction and frost creep is probably minimal and the slopes generally stable, but badlands due to intense gullying may be present in the weakly lithified conglomerate, sandstone, and shale.

Richards Island to Campbell Lake--The geology of this segment of the Richards Island Supply Line is discussed in Section 2.1.2.3.

Campbell Lake to Mouth of North Klondike River--The Arctic Slope segment of this potential corridor for the supply line from Richards Island is underlain by Paleozoic and Mesozoic sedimentary rocks of marine and nonmarine origin. Both the Anderson and Peel Plains are comprised of Devonian clastic sedimentary rocks, which include shale, sandstone, and conglomerate (Hume, 1954; Canada Geol. Survey, 1963). A small area of Devonian limestone and shale occurs just south of Inuvik. The Peel Plateau consists of Cretaceous sandstone and shale (Canada Geol. Survey, 1963), with older Mesozoic sedimentary rocks also present in places (Kunst, 1973). Although no detailed information is available on structures within this region, the sedimentary rock units probably dip gently to moderately and are not strongly deformed.

The central Richardson Mountains consist of Paleozoic and Mesozoic sedimentary rocks. These units have been strongly folded, and exhibit northerly structural trends (Gabrielse, 1957). Lithologies are primarily shale, sandstone, conglomerate, and limestone, with evaporites also present in one unit. Shale and sandstone are the predominant lithologies within the immediate area of the corridor.

The Eagle Plain is a large north-trending synclinorium with Cretaceous strata exposed across its core (Canada Geol. SUrvey, 1963; Martin, 1973). Progressively older Paleozoic strata are exposed along its east, west, and south flanks. Broad, open, north-trending flexures, which extend across the basin's center, parallel structural trends within the Richardson Mountains. Cretaceous shale and sandstone are the predominant lithologies.

The northern Ogilvie Mountains are composed mainly of Paleozoic sedimentary rocks which have been deformed into an east-west-trending fold belt (Martin, 1973). Limestone and shale probably predominate, with lesser amounts of dolomite, conglomerate, and chert. Early Paleozoic and Precambrian volcanic, sedimentary, and metasedimentary rocks predominate within the heart of the range. Principal rock types present along the supply line here include (1) volcanic breccia, tuff, and agglomerate, (2) sandstone, shale, and conglomerate, and (3) quartzite, slate, schist, phyllite, and argillite (Green, 1972). An east-west-trending thrust fault separates this complex from the younger Paleozoic rocks to the north. South of North Klondike Pass, two additional bedrock assemblages are separated by another major thrust fault. The northwestern block consists of Jurassic to Cretaceous sedimentary and metasedimentary rocks, intruded by gabbro, diorite, and syenite. The southeastern block consists mainly of early Paleozoic or Precambrian volcanic, sedimentary, and metasedimentary rocks, with small igneous intrusions.

Most of the Anderson and Peel Plains are covered by drift dating from late Wisconsin regional glaciation. Outwash is particularly abundant where the Anderson Plain is crossed by the supply line corridor, and parts of this segment cross fairly well-drained soils. Postglacial silt deposits formed by alluvial, eolian, and lacustrine processes probably are widespread in low-lying areas, particularly across the lake-dotted surface of the Peel Plain.

The Peel Plateau is more than 1,000 feet above sea level, and is drained by deeply entrenched streams. Although its surficial deposits are not mapped in any detail, much of its surface appears to be covered by hummocky morainal deposits (Prest and others, 1968). Drift cover may be thickest and most continuous where end moraines mark former ice limits near the west flank of the plateau. Drift may be thinnest and least continuous in areas of extensive postglacial stream dissection within eastern parts of the plateau.

The Richardson Mountains are unglaciated and probably are mantled with relatively thick residual soils and loess deposits. Silty sediments derived from weathering, wind transport, and mass wasting probably are abundant on all but the highest slopes, and probably thicken into massive solifluction aprons along valley sides. The low pass at the head of Rock River may have been a major spillway for meltwater flowing westward from the margin of the Laurentide ice sheet. If so, extensive water-scoured bedrock surfaces and coarse outwash gravels would be expected here.

Although no specific details are available on surficial deposits, it is likely that silty residual soils and/or loess are abundant across the Eagle Plain. These sediments probably thicken into massive ice-rich colluvial deposits near slope bases, and should be thin to absent along ridge crests. The generally high terrain followed by the supply line corridor should be underlain by near-surface bedrock beneath a thin cover of rock rubble or stony silt.

Surficial deposits in the northern Ogilvie Mountains probably are comparable to those of the Eagle Plain. Rock rubble may predominate on the higher ridge crests, and rubbly silt on lower ridges and steep slopes. Silty deposits probably thicken downslope owing to redeposition by solifluction; ice-rich, organic, frozen muck may be widely present along slope bases. Along the Blackstone River, outwash sand and gravel may be present in alluvial terraces north of the outer moraine limit.

The northernmost limit of alpine glaciation within the Ogilvie Mountains lies 25 miles north of North Klondike Pass (Vernon and Hughes, 1966). Upvalley from this site, the modern river flood plain is entrenched within a hummocky, lake-dotted drift sheet which covers the valley floor. Younger moraines age occur within a 5-mile sector at the north end of North Klondike Valley. Surficial deposits here are primarily Holocene alluvium and Pleistocene outwash, which occur along the modern river flood plain and in terrace remnants along its flanks. Older glacial deposits are present along both sides of the valley at the margin of Tintina Trench, but apparently do not form a well-defined drift sheet here.

Few major mass-wasting problems are to be anticipated in the generally flat terrain of the Anderson and Peel Plains. Near-surface, ice-rich permafrost, however, would tend to favor chronic solifluction and occasional earthflows even on gentle slopes.

Landslides, slumps, and debris flows may occur frequently along steep flanking slopes of the Peel Plateau, which rise 500 to 1,000 feet above the adjacent plain. Steep slopes also occur along the flanks of stream valleys, which are deeply incised into the plateau. The most serious problems probably would be on slopes underlain by shale and on slopes capped by clayey or silty till or proglacial-lake deposits.

Within the Richardson Mountains, solifluction is favored by steep slopes on shale bedrock or rubble at altitudes above timberline. Sudden catastrophic mass movements here are favored by steep slopes and high relief along the east flank of the mountains and by the generally high seismicity of the region.

Except for minor solifluction and frost creep, no serious mass wasting would be anticipated along that part of the Eagle Plain traversed by the supply line corridor.

In the Ogilvie Mountains, alpine types of mass wasting would prevail. Solifluction might be widespread on uplands crossed by the supply line corridor north of Blackstone River, and landslides and avalanches might occur on oversteepened valley walls within glaciated parts of the Blackstone and Klondike Valleys. Several landslide deposits in valleys tributary to North Klondike Valley have been mapped by Vernon and Hughes (1966). These seem to be associated with two of the numerous faults that later were mapped by Greene (1972) in this area.

Thermal erosion due to thaw of ice-rich permafrost is abundant around the Mackenzie Delta (Mackay, 1963), and probably occurs locally farther south.

Lateral erosion of river banks may be active along the meandering courses of the Mackenzie River, Arctic Red River, and Peel River where these are crossed by the supply line corridor. The local geology of these sites is unknown, but could consist of ice-rich, frozen organic silts. Such sediments would favor extremely rapid bank retreat owing to thermal erosion near river level. Deep stream incision has taken place on Peel Plateau since deglaciation of the region, and probably is continuing today along some drainages.

Although specific data are unavailable, it is likely that the western Richardson Mountains, the Eagle Plain, and the northern Ogilvie Mountains are not undergoing significant erosion today. Relief is moderate here, and slopes tend to be gentle and smoothly rounded. Plant cover and underlying sod usually are sufficient to soak up the typical light rains, and little surface runoff takes place beyond that confined to permanent stream channels.

The steep flanks of deep glacial valleys farther south in the Ogilvie Mountains probably are subject to high rates of modern erosion and mass wasting. In addition, streams in hanging tributary valleys probably are downcutting actively, and glacial deposits are being incised along parts of the main valley floors.

Although permafrost has been extensively studied in the Mackenzie Delta area (Fyles and others, 1972; Mackay, 1963), relatively little is known about its distribution and character farther south. On a generalized regional basis (Brown, 1967), permafrost appears to be essentially continuous along the northern 180 miles of the Richards Island Supply Line corridor, and is discontinuous through the remaining 220 miles to the Tintina Trench.

Thick, ice-rich permafrost is present in the Inuvik area, where it underlies all but the largest lakes and rivers. Farther south, across the plains and plateau between Inuvik and the Richardson Mountains, permafrost also is thick and virtually continuous and probably lies very close to the surface in some wet areas. Within the Richardson Mountains, permafrost probably is continuous but lies at relatively great depth below bedrock or gravel surfaces and along south-facing slopes.

Within the Eagle Plain and the Ogilvie Mountains permafrost probably is discontinuous. The relatively high ridges, which the corridor follows across the Eagle Plain, probably are underlain by permafrost, as are the uplands of the northern Ogilvie Mountains. Within the Ogilvie Mountains, extensive permafrost-free terrain would probably first appear in coarse alluvium of the Blackstone River's modern flood plain. South of the divide, coarse alluvium within the North Klondike Valley would probably contain extensive permafrost-free areas. However, ice-wedge polygons were encountered within the valley during construction of the Dempster Highway (Vernon and Hughes, 1966).

North Klondike River to Pelly Crossing--Bedrock consists of weakly lithified sandstone, conglomerate, and mudstone of Cretaceous or early Tertiary age in the Tintina Trench and of granite and gneiss in the valley of Willow Creek north of Pelly Crossing. Between the North Klondike and McQuesten Rivers, the Cretaceous or Tertiary bedrock is covered by ancient quartzose terrace gravel several hundred feet thick mantled by peat and wind-blown silt that in some places reaches thicknesses of several tens of feet (Hughes and others, 1972). Glacial diamicton (till)--an unsorted mixture of rocks, sand, and silt--extends to depths of several tens of feet in the segment from the McQuesten River to Pelly Crossing, and is mantled by wind-blown silt and by peat that is more than 10 feet thick in low ground and on flat areas. Buried lake clays may be present in the section from the McQuesten River to Stewart Crossing.

The thickness and extent of permafrost decreases from the North Klondike River to Pelly Crossing, but permafrost is generally present beneath north-facing slopes and in fine-grained soils throughout this segment of the corridor. Ice in excess of porosity can be expected in thick peat and silt and also in glacial till. A few open-system pingos are present (Hughes, 1969), indicating the presence of water confined under hydrostatic head beneath the permafrost.

Natural mass wasting due to solifluction and frost creep are minimal, but ice-rich glacial till flows readily when it thaws upon exposure to air and sunlight. If lake clays are present in the river bluffs along the Stewart River, they will furnish glide planes for large-scale landslides.

Steep bluffs carved in gravel and till adjoin the larger rivers and are the sites of rapid gullying. Disturbance to the natural vegetation in these areas will result in accelerated erosion.

Pelly Crossing to Harvey Creek--Bedrock in this segment consists of granite and metamorphic rocks from Pelly Crossing to a point 30 miles to the east and dolomite, limestone, argillite, and metamorphosed rocks of Paleozoic age in the remainder of the segment to Harvey Creek. Throughout most of the Pelly Crossing to Harvey Creek segment, the bedrock is deeply mantled by glacial and glaciofluvial deposits. The westernmost 10 miles of the corridor crosses an outwash plain underlain by several tens of feet of well-sorted sand and gravel (Hughes and others, 1968). Buried lake clay may be present at greater depth. The remainder of the segment crosses ground moraine consisting predominantly of till but including local areas of outwash sand and gravel. Pond deposits and peat attaining combined thicknesses of 10 feet or more are present in many places.

Frost-creep and solifluction are minimal. However, large landslides must be anticipated along steep bluffs of the Pelly River.

The Pelly River to Harvey Creek segment lies within the southern fringe of the permafrost region. Permafrost is widespread beneath north-facing slopes and the poorly drained low-lying terrain that predominates along this segment. Excess ice can be expected in till and peat, and soils subject to excessive subsidence or liquefaction upon thawing are widespread.

Harvey Creek to Black River--Paleozoic carbonates and metamorphic rocks intruded by small granitic plutons predominate as bedrock in the greatly narrowed portion of the Tintina Trench followed by the Pelly River upstream to the vicinity of Hoole Canyon, but small patches of poorly lithified conglomerate, grit, sandstone, and mudstone of Cretaceous or Tertiary age are exposed in a few places in the bluffs and in low hills on either side of the river. Andesite and basalt lava flows of Tertiary age form local mesas along the south side of the trench. In the southeasternmost part of the Tintina Trench, where it passes through the Simpson Range, the mountains to the north consist of high-grade metamorphosed sediments, but bedrock on the floor of this portion of the trench is hidden beneath glacial deposits including till and local patches of outwash gravel and sand (Hughes and others, 1969). Buried lacustrine clay must be expected in steep bluffs along the Pelly River and its incised tributaries. The surface is mantled by thin wind-blown silt and locally by pond silts and overlying peat several feet thick.

The Harvey Creek to Black River segment of the corridor lies within the southern fringe of the discontinuous permafrost zone. Permafrost is present beneath north-facing slopes and beneath thick peat and turf on the poorly drained lowland surfaces that are extensive within the Tintina Trench. The glacial till, buried lacustrine beds, pond silts, and peat commonly contain ice in excess of porosity. The ice-rich soils are subject to liquefaction and moderate subsidence upon thawing.

Slopes are low and mass wasting and erosion at a minimum along much of the corridor, but landslides and badlands will be triggered near steep river bluffs if the vegetation cover is disturbed or the thermal regime altered. Rockfalls and rockslides are frequent and occur on the steep slopes to either side of the trench where it passes through the Pelly Mountains.

Black River to Watson Lake--Bedrock is generally obscured beneath a thick cover of glacial deposits in this segment of the corridor. Weakly lithified coal-bearing sandstone, conglomerate, and mudstone of Paleocene or Eocene age are exposed in bluffs of the Liard River opposite the mouth of the Rancheria River; probably these rocks are widely distributed beneath the surface of the Liard Plain. Tertiary basalt is exposed on the west side of the Liard River and at several points along the Little Rancheria River and probably underlies most of the valley of the Rancheria and Little Rancheria Rivers.

The corridor follows the general course of the Black and Liard Rivers to Watson Lake, passing over thick glacial, glaciofluvial, and alluvial deposits. In the northwestern 30 miles of this segment the rivers are confined between steep bluffs carved in glacial sediments; outwash gravel predominates at the surface near the river bluffs and a mosaic of till and glacial-outwash sand and gravel lies farther back from the bluffs. Pond sediments and peat up to 10 feet thick are present in poorly drained depressions. In the southeastern 30 miles of this segment, the Liard River meanders across a flood plain 3 to 5 miles wide underlain by fine gravel and sand with a surficial cover of peat and silt a few feet thick. Fine-grained silty and peaty sediments 10 feet or more in thickness occupy abandoned channels and sloughs. Away from the river the surface consists of terraces underlain by thick outwash gravel, mantled with several feet of peat and silt.

The Black River to Watson Lake segment lies near the southern limit of permafrost. Ice-rich permafrost is present beneath muskegs and in poorly drained fine-grained soils. Liquefaction and moderate subsidence will develop in these soils when the surface is drained.

Mass wasting is at a minimum in the flat topography of the Liard Plain. However, gullying and possibly landsliding will develop if the vegetation is disturbed near the river bluffs in the northwestern 30 miles of this segment.

Watson Lake to Liard Hot Springs--Bedrock consists largely of limestone and dolomite but shale of late Paleozoic age is exposed in the steep north slope of the Liard River valley in a 10-mile stretch along the corridor extending northwestward from Liard Hot Springs. The surficial deposits consist of glacial sand and gravel in most lowland areas and of glacial till on the uplands. The corridor crosses an area underlain by thick glaciolacustrine silt in a segment about 6 miles long at the mouth of the Coal River and in another lowland about 10 miles wide, 25 miles to the west of Coal River.

The Watson Lake-Liard Hot Springs segment lies within the southern fringe of permafrost. Ice-rich permafrost is present beneath muskegs and in the two lengthy sections where the corridor crosses glaciolacustrine silt. Liquefaction and severe subsidence will develop in these soils when the surface is stripped or trenched.

Mass wasting is at a minimum along much of the route but large-scale, slow landsliding must be anticipated if the surface is disturbed in the areas where steep bluffs are developed in late Paleozoic shale northwest of Liard Hot Springs.

Liard Hot Springs to Muskwa River--The corridor threads its way through narrow valleys lined on either side by mountains developed mostly in limestone and dolomite of Paleozoic age. However, between 15 and 30 miles west of Muskwa River, the corridor crosses steep, dissected ridges carved in Cretaceous shale. Surficial deposits throughout this segment are coarse grained and bouldery, consisting of stony glacial till, outwash, and talus. Although this segment lies just within the southern fringe of permafrost, ice-rich permafrost is rare and subsidence and liquefaction problems are minimal.

Snow and rock avalanches and rockfalls are frequent on the steep slopes of the Muskwa Ranges skirted by this segment of the corridor. The 15-mile stretch where the corridor crosses steep ridges carved in Cretaceous shale are subject to large-scale, slow landsliding.

Muskwa River to Windfall, Alberta--This segment of the corridor crosses a region in which ridge crests are crowned by Cretaceous sandstone and most slopes are underlain by Cretaceous shale. The ridgetops and slopes are only thinly mantled by glacial till, but lowlands and river valleys are underlain by till, outwash, and glaciolacustrine silt reaching thicknesses of hundreds of feet.

The region is considered to lie south of the southern fringe of permafrost; nevertheless, permafrost is present in isolated areas beneath muskegs at high altitudes, for example on the ridges and interfluves generally followed by the corridor. Though permafrost is thin, it disrupts the moisture regime and enhances the landslide susceptibility of the Cretaceous shales.

Large-scale, slow landslides, some ancient and some still active, are widely distributed on slopes underlain by Cretaceous shale. Disturbance of natural drainage by construction activities enhances the tendency for landslides to develop, reactivating some ancient slides and causing new ones. Ancient and modern landslides are also widespread in the steep canyon walls of entrenched rivers such as the Peace, the Wapiti, the Athabasca, and the Smoky Rivers. Here, Cretaceous shales and glaciolacustrine silts are the slide-susceptible element. Construction activities in these places could trigger new slides.

Mineral Resources

Metallic and Nonmetallic Mineral Resources--The principal deposits of metallic and nonmetallic mineral resources in the area traversed by the Fort Yukon Corridor proper and by the Richards Island Supply Line occur in southern Yukon Territory. They are the (1) Clinton Creek asbestos deposit just east of the International Boundary, (2) the historic Klondike placer-gold area near Dawson, (3) gold placers at Clear Creek about 60 miles southeast of Dawson, and (4) the Anvil Mines Corp. Ltd. property 130 miles northeast of Whitehorse near Ross River on the Campbell Highway. According to Douglas (1970, Map 1252 A), and Little and others (1970), production from the Clinton Creek deposit began in 1967; total reserves and production are more than 15 million tons of ore. The Klondike district was one of the richest gold-placer fields in the world and was the source of more than half the placer gold of western Canada. During the 1960's nearly all of the placer gold mined in Canada came from this district (Little and others, 1970, p. 517). Several other placer-gold streams are near but outside the corridor, as is the Keno Hill silver-lead-zinc area. Lead-zinc-silver ore at the Anvil property was mined at the rate of 6,600 tons per day in 1970; concentrates are trucked to Whitehorse for rail and marine shipment. Reserves as of 1970 were about 63,500,000 tons of ore (Craig and Laporte, 1972, p. 94-96). In addition, there has been much recent prospecting for base metals throughout the southern half of Yukon Territory.

No data are available on specific deposits of sand, gravel, or rock suitable for crushing and use as a construction material. Adequate quantities of all are probably available in most parts of the Fort Yukon Corridor should it be selected for a pipeline.

Oil and Gas--A 300-mile-wide zone along the Fort Yukon Corridor would be close to the Eagle sedimentary province and the Whitehorse and Bowser basins and would include the southwestern part of the Tathlina sedimentary province and the western edge of the oil and gas producing region in northeastern British Columbia and northwestern Alberta. The Old Crow, Mackenzie, Banks, Peel, Anderson, and most of the Tathlina sedimentary basins or provinces would be outside this zone.

Sedimentary rocks in the basins (table 2.1.2.3-1) north of the 60° N. latitude are similar to rocks that elsewhere have generated recoverable accumulations of hydrocarbons. However, only the southwestern part of the Tathlina province where gas reserves of 3 to 7 tcf (trillion cubic feet) (de Wit and others, 1973, p. 204) have been established, has been explored.

The amount of gas potentially recoverable from the incompletely explored areas near the corridor aggregates no more than 10 tcf (table 2.1.2.3-1). Actually, less than half that amount probably would ultimately be discovered. A pipeline, which crosses to the coast, already exists south of the Bowser basin. In the maturely explored oil and gas province in British Columbia and Alberta the Fort Yukon Corridor follows a pipeline system developed for the reserves and potential described in Section 2.1.2.3.

Seismicity

The earthquake history along the Fort Yukon Corridor is short relative to the time over which strains accumulate to produce an earthquake, hence the historic record of seismicity is a limited guide to future seismic risk. Earthquakes of magnitude 6 and larger are potentially destructive, and even earthquakes of magnitude 5 may cause local damage. North of 60° N.

latitude, the seismic history of Canada is probably complete since the early 1930's for earthquakes as small as magnitude 6 and since the late 1950's or early 1960's for shocks as small as magnitude 5 (Stevens and Milne, 1973; Leblanc and Wetmiller, 1974). The historic record is somewhat better for eastern British Columbia and Alberta.

The historic record indicates that the level of earthquake activity along the Fort Yukon Corridor is low except for the Richards Island Supply Line along which the level is locally high. Along the main corridor the area of greatest known seismicity is the Watson Lake region within which earthquakes as large as magnitude 5.0 have occurred within 25 miles of the corridor. Elsewhere along the main corridor epicenters of earthquakes as large as magnitude 4.4 have been located within 50 miles of the corridor. The Richards Island Supply Line traverses a highly active seismic zone in the Richardson Mountains. Epicenters for two earthquakes in the magnitude range 6.25 to 6.50 are located within about 25 miles of the corridor, however, the accuracy of the epicenters may be no better than 60 miles (Leblanc and Wetmiller, 1974).

The earthquake potential along the Fort Yukon Corridor specified in terms of maximum expected earthquakes is summarized in Table 8.1.2.9-11. The maximum expected earthquake is the largest earthquake that on the basis of existing knowledge may reasonably be expected to occur along a specified segment; it everywhere equals or exceeds the largest known historic earthquake. The zonation of the corridor might be further refined if more complete geologic and geophysical data were available.

At present, no faults with surface expression are known to be active in this region. However, detailed geologic field investigations in areas of high seismicity might reveal evidence for geologically recent movements (Stevens and Milne, 1973). Without knowledge of the seismically active faults along and adjacent to the corridor, there is no basis for assigning the maximum expected earthquakes to a specific fault, and the occurrence of the maximum expected earthquake anywhere along the corridor must be considered possible.

Soils

Regosols and Cambisols are the major soil types found along the Fort Yukon Corridor between Campbell Lake and North Klondike River. With the exception of the Ogilvie Mountains, the area is unglaciated and the soils have developed on colluvium. The Regosols are prone to erosion in the form of mass wasting and solifluction, and to formation of stone polygons. Lithosols are found in the section of the corridor through the Richardson Mountains.

From North Klondike River to Watson Lake, Cambisols are the dominant soil type. Most of this area is classified as Boreal Forest, with the best stands occurring in protected lowlands. Some Lithosols and associated Regosols are found in the Pelly Mountains.

Luvisols and minor occurrences of Solonetz soils are predominant from Watson Lake to Windfall.

Water Resources

Surface Water

The major drainages crossing the Fort Yukon Corridor include the upper reaches of the Yukon, Liard, and Peace Rivers. Although the exact number of streams is not certain, about 55 major and 605 minor stream crossings would be required between the Alaska-Yukon border, Richards Island Supply Line, and the proposed route near Windfall, Alberta (see Table 8.1.2.9-10).

A summary of selected streamflow data collected by the Water Survey of Canada is shown in Table 8.1.2.4-1.

On the larger streams in the northern Cordilleran Region the maximum flows almost always occur during snowmelt in May or June. Many of these streams also have significant flow from glaciers. The probability of floods resulting from summer rainstorms is greater on the smaller upland watersheds. The magnitude of winter flow varies widely not only from year to year but also between basins of comparable size. Streamflow in some small basins may reach zero in winter. For example, St. John Creek (drainage area, 77.7 square miles) has no flow for many days in winter. Maximum discharge for selected streams is shown in Table 8.1.2.4-1. Spring breakup may occur as early as April.

The Richards Island Supply Line corridor lies in the Interior Plains. Most of the major streams which would be crossed by this Corridor have been gaged. No data are available for drainage basins smaller than 3,000 square miles. Maximum flow on the larger streams usually occurs during snowmelt in May or June. Minimum flow usually occurs in March. The larger streams flow throughout the winter.

The Peel River carries relatively large amounts of suspended sediment during most of the open-water season. During 1973 the Peel River above Fort McPherson had suspended-sediment concentrations ranging from 198 to 1,900 mg/l (Davies, 1974).

Surface waters in the Fort Yukon Corridor vary in degree of mineralization and hardness depending on whether they traverse the Cordilleran or Interior Plains Regions. Streams originating in the Cordilleran Region contain medium-hard water of the bicarbonate type. Many of the tributaries which flow through the Interior Plains increase in hardness and sulfate content.

During the winter months when streams are frozen and the terrain is snow covered, suspended-sediment concentrations are low, generally less than 70 mg/l (Stichling, 1974). Suspended-sediment concentrations during the open-water season are quite variable. Highest concentrations occur during spring breakup and summer-storm events.

Ground Water

The Fort Yukon Corridor passes through two hydrogeologic regions: the Northern and the Interior Plains (see Figure 2.1.2.5-7). Most of the regions have been glaciated and are mantled with glacial and nonglacial surficial deposits. That portion of the corridor north of 60° N. latitude is in the discontinuous permafrost zone, except for the northern part of the Richards Island Supply Line which is in the continuous permafrost zone.

Ground-water resources in the continuous permafrost zone have not been developed. The village of Fort McPherson, along the northern part of the

Table 8.1.2.4-1 Summary of selected streamflow records along the Fort Yukon Corridor

Station	Name	Drainage area (sq.mi.)	Location	Discharge records	Type of gage	Operation	Mean (cfs) (in)	Max. daily (cfs)	Min. daily (cfs)	Remarks
	YUKON RIVER:									
09BA001	Ross R at Ross River, Y.T.	2,800	61°59'40" 132°22'40"	60-64 65-	M R	C C	2,320 11.25	26,200 6-1-72	152 4-10-72	
09BC002	Pelly R at Ross River, Y.T.	7,670	61°59'12" 132°26'54"	54-59 60-	R R	S C	6,710 11.88	71,000 6-7-64	380 3-24-69	
09BC001	Pelly R at Pelly Crossing, Y.T.	19,700	62°49'47" 136°34'50"	51-60 61-	M R	C C	13,900 9.58	146,000 6-11-64	1,020 3-17-56	
09DD002	Stewart R at Stewart Crossing, Y.T.	13,500	63°22'56" 136°40'59"	61-	R	C	14,600 14.69	152,000 6-11-62	900 3-18-69	
09EA003	Klondike R ab Bonanza Creek, Y.T.	3,010	64°02'34" 139°24'28"	65-	M	C	2,200 9.93	22,600 5-29-72	180 4-2-70	
09EB001	Yukon R at Dawson, Y.T.	106,000	64°04'20" 139°25'21"	45-52 54-55	M M	C S	78,000 9.99	526,000 6-11-64	6,350 2-22-51	Regulated since 1969.
	MACKENZIE RIVER:									
10AB001	Francis R nr Watson L, Y.T.	4,950	60°28'26" 129°07'08"	63-	R	C	5,870 16.1	b39,100 6-12-64	580 3-22-73	
10AA001	Liard R at Upper Crossing, Y.T.	12,500	60°03'00" 128°54'00"	60-	M	C	14,100 15.3	108,000 6-2-72	1,750 3-23-66	
10AC002	Dease R at McDame, B.C.	2,700	59°11'20" 129°12'44"	58-	R	C	3,550 17.9	b34,200 5-31-72	415 4-26-66	
10AD001	Hyland R nr Lower Post, B.C.	2,600	59 57'03" 128°09'03"	47-64 65-	M R	S C	4,970 26.0	59,800 6-10-61	460 3-25-72	
10BB001	Kechika R at mouth, B.C.	8,790	59°36'55" 127°18'37"	62-	R	C	8,540 13.2	b69,900 6-12-64	895 3-29-72	
10BC001	Coal R at mouth, B.C.	3,650	59°41'29" 126°57'02"	61-	R	C	3,760 14.0	b39,100 7-14-68	530 3-28-72	
10BE001	Liard R at Lower Crossing, B.C.	40,300	59°24'45" 126°05'50"	44 46-71 72-	M M R	S C C	40,500 13.0	293,000 6-12-61	4,400 3-21-66	

continued on next page

1/ Water Survey of Canada annual data reports.

Table 8.1.2.4-1 Continued

Station	Name	Drainage area (sq.mi.)	Location	Discharge records	Type of gage	Oper-ation	Mean (cfs) (in)	Max. daily (cfs)	Min. daily (cfs)	Remarks
10BE007	Trout R at Mile 487 Alaska Hwy., B.C.	461	59°20'11" 125°56'15"	70-	R	C	477 13.2	b1,900 5-31-72	152 3-29-72	
10BE004	Toad R ab Nonda Creek, B.C.	993	58°51'20" 125°22'50"	61-	R	C	1,550 21.2	b18,900 7-11-63	121 3-21-69	
10CB001	Sikanni Chief R nr Fort Nelson, B.C.	800	57°14'20" 122°41'25"	44-57 58-	M M	S C	905 15.4	16,900 6-28-65	14.7 3-7-70	
10CD001	Muskwa R nr Fort Nelson, B.C.	7,600	58°47'18" 122°39'33"	44-	M	C	7,050 12.6	141,000 6-16-71	187 3-6-69	
10KA001	Mackenzie R at Norman Wells, N.W.T.	606,000	65°16'54" 126°50'58"	43-56 62-	M R	S C	288,000 6.45	900,000 7-25-72	74,600 3-11-69	Richards I. Supply Line
10LA002	Arctic Red R nr Martin House, N.W.T.	5,840	66°47'10" 133°06'00"	68 69-	R R	S C	a5,100 12	b193,000 7-22-70	300 3-2-72	Richards I. Supply Line
	MACKENZIE RIVER (PEEL CHANNEL):									
10MC002	Peel R ab Fort McPherson, Y.T.	27,300	67°13'15" 134°56'45"	69-	R	C	(c)	176,000 6-4-71	1,620 4-15-72	Richards I. Supply Line
	PEACE RIVER/MACKENZIE RIVER:									
07FA001	Halfway R nr Farrell Creek, B.C.	3,630	56°13'40" 121°28'50"	61-	R	C	2,830 10.6	70,000 6-29-65	216 3-8-71	
07FD002	Peace R nr Taylor, B.C.	38,300	56°08'09" 120°40'13"	44-50 51-59 60-70 71-	M M R	S C C	48,100 17.1	b354,000 6-13-64	6,000 3-24-52	Regulated since 1967.
07FC003	Blueberry R bl Aitken Creek, B.C.	676	56°40'38" 121°13'15"	64-	R	C	203 4.08	b9,520 6-29-65	0.18 3-11-69	
07FC002	Saint John C nr Montney, B.C.	77.7	56°25'27" 120°55'30"	62-	M	C	26.1 4.56	1,070 4-26-63	0 Many days	
07FD001	Kiskatinaw R nr Farming-Ton, B.C.	1,380	55°57'25" 120°33'45"	44-50 62-64,66-65	M R R	C C S	420 4.13	14,600 6-14-68	0.58 3-27-48	
07GE001	Wapiti R nr Grande Prairie, Alb.	4,350	55°04'20" 118°48'10"	17-18 60-71	M M	S C	3,830 11.46	130,000 6-13-72	100 4-19-63	

continued on next page

Table 8.1.2.4-1 Continued

M	Manual gage.	a	Estimated.
R	Recording gage.	b	Maximum instantaneous discharge.
C	Continuous operation.	c	Insufficient data.
S	Seasonal operation.		

NOTE: The number of years used to compute or estimate the mean discharge does not necessarily correspond to the full period of continuous gage operation shown. Means for seasonal records were estimated in a few cases. These estimates should be reasonably reliable, since winter flows were generally low.

The maximum daily discharges are shown for most stations because that was all that was published. Instantaneous discharges are shown when they are available. The maximum daily discharge may be considerably smaller than the instantaneous peak for small and intermediate streams. Maximum stages are not shown, but they may or may not have occurred at the time of maximum discharge. The highest stage might occur as the result of an ice jam.

Caution should be used in interpreting minimum-flow figures. They are the lowest values published, but lower values may have occurred during periods of seasonal observations.

Richards Island Supply Line, obtains water from a surface water source (Brandon, 1965). However, ground water could probably be obtained from alluvium adjacent to the Peel River. Although there are no ground-water quality data available for the Richards Island Supply Line, the shallow aquifers along the pipeline route should have the same general qualities that are identified in the streamflow.

In the areas of discontinuous permafrost, villages have developed their water supplies in the unfrozen alluvial aquifers adjacent to the rivers. In the Interior Plains, the ground-water resources are highly developed. Low-yield domestic wells penetrate the till deposits; municipal and industrial wells pump water from the sedimentary bedrock units.

Ground-water quality along the route varies from waters of calcium or magnesium bicarbonate type with moderate concentrations of dissolved solids to those of calcium or magnesium sulfate type with high dissolved-solids concentrations.

Vegetation

This treatment of the vegetation is largely based upon Fremlin (1974), Hernandez (1974), CAGPL (1974e, Section1.4) and Rowe (1972).

Richards Island to Fort McPherson

The vegetation of this segment is similar to that discussed for the proposed route (Section 2.1.2.6) and is not repeated. That discussion, and the paper by Hernandez (1974), on which it is mainly based, is generally applicable along this segment (Figures 8.1.2-1, 8.1.2.1-2 and 8.1.2.4-2).

Fort McPherson to North Klondike River

This portion of the corridor (Figure 8.1.2.4-2) lies within the Forest-Tundra, Alpine Tundra and Boreal Forest Formations. It crosses the Peel Plateau, with its mosaic of mature forest-tundra, mixedwood, low shrub heath, and extensive tussock communities, to the Richardson Mountains and the Eagle Plain where alpine tundra vegetation is an important element. Communities of dwarf willows (Salix phlebophylla), Lapland cassiope and lichens occur on well-drained, moderate slopes. Cassiope and alpine blueberry occur on steeper, better-drained slopes and dwarf willow and spike moss (Selaginella) occupy high rocky ridges. Lichens are constituents of both of these communities (CAGPL, 1974e). Poorly drained depressions have a community of sedges (Carex microchaeta), cottongrass, and sphagnum mosses. Large areas of rolling hills at lower elevations bear cottongrass tussock communities. Scattered white spruce with an understory of heaths is found on low, interior valley slopes.

The Eagle Plain is within the Alpine Forest-Tundra Section of the Boreal Forest (Rowe, 1972). Stunted white spruce in open park-like stands extend to tree line at 3,500 to 3,800 feet. On northern and eastern aspects, alpine fir (Abies lasiocarpa) occurs near tree line. Black spruce occupies similar exposures at lower altitudes, and on more favorable sites Alaska birch (Betula papyrifera var. humilis) is mixed with white spruce. Tamarack and poplar species occur infrequently.

Alpine Tundra occupies the higher elevations of the Ogilvie Mountains and dwarf shrub communities extend down to contact with stunted forests at elevations of 3,000 to 4,000 feet.

Alaska-Yukon Border to Pelly Crossing

Most of this segment lies in the Dawson Section of the Boreal Forest Formation (Rowe, 1972) (Figures 8.1.2.1-2 and 8.1.2.4-1).

Valley slopes have pure stands of white spruce or mixtures of spruce with Alaska paper birch or trembling aspen. Spruce reaches its best development on slopes above valley floors subject to cold air drainage. Birch and aspen are maintained by fire and are best developed on dry hilltops and steep southern exposures. Stunted black and white spruce and dense alder and willow communities border the streams. Alpine fir is mixed with the spruces at higher elevations.

A number of endemic species, several of which may be of limited distribution and rare, have been reported from Eagle (CAGPL, 1974e) and may also occur here.

In the Eastern Yukon Section of the Boreal Forest, lower slopes and valley terraces are dominated by white spruce-lodgepole pine forests and tamarack is mixed with black spruce in bogs.

Pelly Crossing to Watson Lake

From Pelly Crossing the corridor continues through the Eastern Yukon Section with vegetation as mentioned in the paragraph above. Alpine fir continues on higher slopes where it is mixed with white and black spruce and birch. North- and east-facing slopes often lack forest cover but south- and west-facing slopes are favorable to white spruce, aspen and birch.

The corridor follows the Pelly and Hoole Rivers and descends from the Yukon Plateau to the Liard Plain via the Black River and then follows the Liard River to Watson Lake (Figure 8.1.2.4-1). The Liard Plain is in the Upper Liard Section (Rowe, 1972) which includes some of the most favorable forest areas in the Yukon. White spruce and balsam poplar form pure stands on alluvial flats of the broad river valleys. Black spruce and lodgepole pine occur as pure stands or mixtures above the flood plains, the latter species being abundant as a result of fire history, especially on sandy terraces. Plant species of rare and local distribution occur in the Pelly Mountains (CAGPL, 1974e).

Watson Lake to Windfall

The Upper Liard Section continues to the vicinity of Liard Hotsprings Provincial Park (Figure 8.1.2.4-3), the corridor passing through small areas of alpine tundra near Muncho Lake, and enters the Northern Foothills Section. This section fronts the Rocky Mountains in the Peace River district of British Columbia (Figure 8.1.2.4-6). Black and white spruce and lodgepole pine are associated on high plateaus and on fine-textured soils in areas of low relief. Black spruce occupies poorly drained organic soils of the lowlands. Alpine fir, an associate of white spruce on lower slopes, increases in abundance with increasing altitude and merges with alpine tundra at about 5,000 feet.

The Lower Foothills Section (Rowe, 1972) begins in the vicinity of Wonowen, B.C., and extends to the vicinity of Fort Nelson. The forests are transitional between the communities of the Boreal and Subalpine Forest Formations in the Rocky Mountain foothills and at low elevations in the front ranges. Older forest stands of white spruce, frequently with black spruce, are important, but the most distinctive species is lodgepole pine which, with aspen and balsam poplar, becomes dominant following fire. Alpine fir and balsam fir are common locally in the main body of the section.

From just north of Fort St. John, B.C., to the Smoky River crossing, the corridor lies in the Mixedwood Section. The characteristic forests of well-drained uplands are mixtures of balsam poplar, trembling aspen, white and Alaska birches, white spruce, and balsam fir. Aspen covers the largest areas as a result of disturbances. Jack pine occurs on sandy areas and dry till soils and is mixed with black spruce on higher hills. Black spruce and tamarack are associated in areas of muskeg.

In the vicinity of Fort St. John, B.C., and Grande Prairie, Alberta, there are outliers of Aspen Parkland. This parkland, discussed for the proposed route (Section 2.1.2.6), borders the prairie farther south and is here mixed with outliers of prairie grassland now under cultivation.

Southeast of the Smoky River the corridor passes once again into the Lower Foothills Section, previously described, and continues to the intersection with the proposed route near Windfall.

Wildlife

The wildlife data contained in this section were drawn, except as noted, from the Applicant's document CAGPL (1974e).

Fish

Stream gradients are relatively steep over most of the Fort Yukon Corridor, and there is large variation in annual flow. Floods are frequent, reaching peaks after spring breakup.

The fish fauna west of the Continental Divide is similar to that reported previously in this Statement for the Porcupine River drainage (Section 8.1.2.1) and by Griffiths et al. (1974). East of the divide the fauna is similar to that reported for the Mackenzie River drainage (Section 2.1.2.7).

Near the head of the Mackenzie Delta, the corridor for the supply line from Richards Island crosses the Mackenzie and Peel Rivers. This area has low stream gradients. After the corridor crosses the Richardson Mountains it is in the watershed of the Porcupine River where gradients are steep. The fish fauna is similar to that described for the Porcupine River in Section 8.1.2.1.

Mammals and Birds

Alaska-Yukon Border to North Klondike River--This 123-mile segment of the Fort Yukon corridor passes between areas normally occupied by the Porcupine and Fortymile caribou herds, between which interchange has occurred. Along the Yukon River, moose, beaver, muskrat, mink, and otter occur. Marten, lynx, fox, black bear, and wolverines are moderately common to abundant, but grizzly bears are not common. Dall Sheep are found in the Ogilvie Mountains and range into the general area of the corridor to use mineral licks, which are considered to be critical habitat.

Generally, birds typical of the Boreal Forest and riparian habitats are present. They include, among others, gray jay, chipping sparrow, ruby-crowned kinglet, and darkeyed junco. The area is not a productive waterfowl habitat, though many species would be expected to occur. Peregrine falcons have been observed in the area and other raptors are certainly present. A species list would contain many of the species tabulated for the Northern Mackenzie segment of the proposed route in Table 2.1.2.7-10.

Inuvik to North Klondike River--At the mouth of the North Klondike River the Fort Yukon Corridor is joined by the supply line from Richards Island. An 87-mile segment of the corridor from Richards Island and the entire 15-mile Parson's Lake Lateral are common to the proposed route, and to the Interior, Fort Yukon, and Fairbanks Corridors. Wildlife of these common corridors is discussed in Section 2.1.2.7. A 382-mile segment parallels the Dempster Highway from Inuvik, N.W.T. This segment would be common to both the Fort Yukon and Fairbanks Corridors (see Figure 8.1.2.4-2).

This segment passes through country inhabited by wolves, grizzly bear, caribou, moose, Dall sheep, and other representative mammals of the Boreal Forest and tundra. From Inuvik to Ft. McPherson the mammals would be essentially the same as those along the proposed route between Ft. McPherson and Travaillant Lake Junction (Section 2.1.2.7). South of Ft. McPherson a major concern is that the wintering areas and migration routes of the Porcupine caribou herd, for which the headwater areas of the Peel and Porcupine Rivers are important winter range. There are also Dall sheep in the part of the corridor in the Ogilvie Mountains.

The species of birds along this section would be similar to those along the Interior Route (See Section 8.1.2.1; also, Table 2.1.2.7-10). Waterfowl are abundant in the Eagle River valley and between Fort McPherson and Inuvik. Peregrine falcons are known to be in the Campbell Lake area near Inuvik, and along the Ogilvie River.

North Klondike River to Pelly Crossing--This segment is common to both the Fort Yukon and Fairbanks Corridors (Figure 8.1.2.4-1).

Wolf, lynx, and marten are common in the forested areas along this segment. The beaver population is reported to be high along the Stewart River and Crooked Creek. Muskrat, mink, and otter also occur in thse areas. Moose, black bear, and some grizzlies are present along the segment and mule deer are known to occur near Minto.

The birds would be generally the same as in the first segment. The Stewart River is a much more productive area for waterfowl than the Klondike, and its open flats and sandbars are a resting area for migrating sandhill cranes.

Pelly Crossing to Watson Lake--Moose winter in the Pelly River valley south of the Anvil Range. There are large concentrations of Dall sheep on Tay Mountain at the west end of this range. The Fort Yukon Corridor crosses both sheep and caribou ranges near the Canol Road. The Hoole and Black River valleys are good moose habitat. In the St. Cyr Range along these rivers, grizzly bears are common and the dark phase of the Dall sheep (stone sheep) and woodland caribou occur. Mountain-goat habitat in the Simpson Range is near this segment of the corridor. Both summer and winter ranges for moose are found along the Liard River. In the more rugged sections of this area wolverines, wolves, red foxes, and marten are common and many of the streams contain beaver, muskrat, mink, and otter.

Some raptors would be expected to occur in the rough terrain along this segment; however, the McArthur Range to the north of the corridor is reported to have a "paucity of birds," which would reduce the probability of peregrine falcons being present.

Watson Lake to Windfall, Alberta--Beginning about 100 miles southeast of Watson Lake the corridor passes for about 85 miles through rugged mountain-goat and Dall sheep habitats in the Muskwa Ranges and near Muncho Lake and Stone Mountain Provincial Parks. At Stone Mountain herds of 200 to 300 stone sheep are reported and caribou and grizzly bear occur. Moose concentrate in the valleys in winter. The 55-mile segment of the corridor along the Muskwa River is considered excellent moose range (up to 90 moose observed per hour flying time) with large populations of wolves. The rest of the corridor generally parallels the Alaska Highway and wildlife populations tend to be scattered. Some whitetail deer habitat is near Fort St. John. The valleys of Stoddart Creek, St. John Creek and the Peace River are good winter range for moose and mule deer.

Because of fluctuating water levels, steep river-banks, and rapid erosion, much of the area along the Alaska Highway apparently is poor waterfowl habitat. Near the British Columbia-Alberta border trumpeter swans breed in lakes near Grande Prairie. Along the corridor south of the Peace River, a number of lakes, particularly North Cline and Charlie Lakes, are used by migrating waterfowl.

Ecological Considerations

The major ecosystems crossed or otherwise affected by this corridor north of its junction with the proposed route near Windfall, Alberta, with two exceptions, are identical with those previously discussed for the proposed route (Sections 2.1.2.8 and 3.1.2.8). The Richards Island Supply Line makes two extensive crossings of the Alpine Tundra Ecosystem. The Alpine Tundra has been previously discussed for the Interior Route (Section 8.1.2.1).

The corridor from the Alaska-Yukon border to Windfall lies mainly within the major Boreal Forest Ecosystem. Although the proposed route, south of Norman Wells, and the Fort Yukon Corridor, excluding the Richards Island Supply Line in part, traverse a forest-dominated ecosystem there are large differences in their respective subsystems. No attempt is made to differentiate a hierarchy of subsystems but the differences are reflected in some degree by the discussions of vegetation and wildlife.

Economic Factors

The economic factors, past and present, in the Fort Yukon Corridor differ considerably from those in the region traversed by the proposed route. The Fort Yukon Corridor traverses a part of Yukon Territory that is known for past and present gold, silver, and other metal mining and exploration. A large part of the corridor follows existing highways. Southward from the border of Yukon Territory at Watson Lake, the corridor follows the Alaska (Alcan) Highway through British Columbia to Dawson Creek, in a region that has been developed chiefly since 1946 by tourism, petroleum exploration and development, some farming, and increased related activities, including a railhead at Dawson Creek and Fort St. John.

The principal economic activities in the Yukon Territory are in the Federal, Territorial and local government sectors, tourism, transportation, various services, mining, and exploration. The 1972 payroll was about $60 million, of which approximately $20 million was in the three levels of government, $15 million in mining industry, and $25 million in the transportation, tourism, and services fields. Much of the mining in the territory is located close to the Fort Yukon Corridor at Faro, Macmillan Pass area (north of Watson Lake), Keno Hill-Elsa, Dawson area, and at Clinton Creek (near the Alaska-Yukon border).

Mining produces the major exportable commodities. Zinc, lead, asbestos, copper, silver, and gold are the chief commodities. A minor amount of coal has been produced for local use. Statistics for the harvest of timber, furs, and game in this area are not available, but these activities and products are probably of minor economic importance.

The work force in Yukon Territory in 1971 was estimated to be about 3,600 males, aged 15 to 64 inclusive. A large part of this group is employed in Whitehorse. Approximately 1,050 people are employed in a wage economy in the area along this corridor, and about 75 percent of them are directly employed in the mining activities at Clinton Creek (200), Keno-Elsa (286), and Faro (350).

Without the pipeline, the economic trend in this area would be dependent in large part on mining and mineral exploration activities. Mining and milling operations at Keno-Elsa and Faro probably will continue at the same level, barring significant changes in the mineral economy. Gold mining in the Dawson area has been declining in recent years and this trend probably will continue even with a rising gold price. It is reported that the asbestos mining operation at Clinton Creek will be closed in the very near future. Several promising lode prospects are being explored, and it is possible that some new minable deposits might be developed in the next decade. The tourist and service sectors probably will remain stable or show a moderate increase commensurate with increases in travel population and the mineral-related economic factors.

Sociological Factors

The population of Yukon Territory was about 18,000 in 1971, with 11,000 people in Whitehorse and 7,000 in various small communities. Approximately 4,100 people reside in the small settlements along the Fort Yukon Corridor. Over two-thirds of the 18,000 people are Caucasian, and the remaining group is made up of 2,800 Indians as defined by the Federal Indian Act and 3,000 Metis. The figures for non-status Indians and Metis may not be reliable, and Yukon Territorial government officials believe that in 1971 this entire group was about 1,600 (5 percent). There are approximately 900 Indians in the approximately 4,100 population along the corridor.

Local government in the Indian communities is generally handled by an elected council and a Native band chief. Stewart Crossing and Pelly Crossing have no council, and Clinton Creek and Elsa are apparently operated as mining company towns.

No specific information is available on the characteristics of housing, water services, waste disposal, and educational and health services. All of the communities have electric service provided by diesel-powered plants. In general, some stores, lodging accommodations and automobile service stations are present in each community. Clinton Creek and Faro have been established within the past 5 to 6 years and have adequate modern housing and buildings.

Information on area trends in population and community structure is not available, but in general advances have been made commensurate with the general regional growth that is particularly related to developments in highway tourism and mining and mineral exploration.

Presumably the only sites where noise levels might be of environmental concern would be near mining operations or main highways.

Land Use

The principal human activities in the region traversed by the Fort Yukon Corridor are mining, hunting, and tourism. Much of the region is forested with major stands of possibly merchantable timber. Principal kinds of trees include spruce, pine, birch, and aspen. Except near Dawson, Y.T., where there is placer-gold mining, there is no intensive land use. The Porcupine caribou herd ranges over part of the area that would be crossed by the Richards Island Supply Line. Construction activity might affect movement and, in time, cropping of the herd.

Archeological and Historic Values

The earliest evidence of man on the northwestern plains of Alberta consists of scattered finds of fluted points thought to date to about 12,000 years ago, shortly after the recession of the last glacier. At that time, man probably hunted the now-extinct megafauna. By about 8,000 years ago, environmental conditions similar to those of the present day became established in this area. In the central Yukon, spruce forests had become established by 8,700 years ago. The early inhabitants of both regions were primarily bison hunters. Archeological remains of these prehistoric hunters have been found at Pelly Farm Site adjacent to the Fort Yukon Corridor, and on the middle Stikine River in British Columbia.

About 5,500 B.C., a generalized Boreal-Forest adaptation to hunting, fishing and trapping appeared. This cultural assemblage, possibly influenced by contact with Asiatic migrants, was based predominantly on a microblade and core technology and was widespread throughout the interior Yukon, the Stikine River area, and east of the Rocky Mountains as far as Calling Lake, Alberta.

Between 2,500 and 1,500 B.C., the intermontane region underwent climatic cooling, with a correlative advance in valley glaciers. Generally, a microblade technology persisted, but in some areas, more southerly plains-like influences in projectile points (Oxbow-like) appeared. After the White River ash falls of about A.D. 300 to 500, the forerunners of the historic Athabascan occupants appeared. This phase is characterized by a distinct decline in quality and quantity of stone implements. Generally, the archeological record of both the plains and intermontane regions indicates a marked reduction in population, possibly due to environmental effects of the White River ash fall. Archeological assemblages from this period are characterized by small side-notched projectile points.

Recreation and Esthetic Resources

From Eagle, Alaska, the corridor follows the Yukon River through Boreal Forest to Dawson, Y.T. Then it follows the Territorial highway to Pelly Crossing, where it heads directly for Watson Lake via the Pelly and Liard River valleys. For about three quarters of the way between Alaska and Watson Lake, the corridor occupies the Tintina Trench, which is a very distinctive feature and resembles the Rocky Mountain Trench in size and orientation. North of Pelly Crossing, the terrain is rolling and forested.

Along the Pelly River, the corridor re-enters the Tintina Valley and follows the very narrow, straight valley of the Hoole River. After crossing the Simpson Range into the Liard watershed, the corridor proceeds down the mile-wide valley of the Black River and onto the open rolling terrain of the Liard Plain. From Watson Lake to Dawson Creek, B. C., it follows the Alaska Highway except in the vicinity of Fort Nelson, where it leaves the highway for 75 miles. Between Liard Hot Springs and Summit Lake, the Fort Yukon Corridor crosses the northern end of the Rocky Mountains and follows the highway across the Rocky Mountain Foothills and Alberta Plateau. Between Fort St. John and Grande Prairie, the terrain is partly gently rolling, cultivated land with a network of local roads.

The Richards Island Supply Line section of the Fort Yukon Corridor begins on Richards Island, a part of the low-lying Mackenzie Delta. From Campbell Lake, the corridor follows the Dempster Highway across the Peel Plateau, the Richardson Mountains, the Eagle Plain, the Porcupine Plateau, and Ogilvie Mountains to Dawson, where it joins the corridor of the proposed Alaska supply line.

The corridor passes close to or through Liard River Hotsprings, Muncho Lake Provincial Park, and Stone Mountain Provincial Parks, all in northern British Columbia. In addition to these official recreation areas, there are natural areas and features of potential value for recreation in the region crossed by the corridor. Recreation resources are closely associated with the terrestrial and marine biotic resources, which are discussed elsewhere in this volume (see subsection on wildlife of the Fort Yukon Corridor). In addition to such wildlife-related recreation activities as hunting, fishing, and photography, other outdoor pastimes which could be enjoyed in the region include sightseeing, float tripping and canoeing, snowmobiling, skiing, hiking, and camping.

Air Quality

Air quality in the area traversed by the Fort Yukon Corridor is probably generally similar to that along the proposed route (Section 2.1.2.14). Existing highways extend along much of the Fort Yukon Corridor (Figures 8.1.2.4-1, 2, and 3). Therefore, because of exhaust emissions from mobile and stationary internal combustion engines, air quality is probably lower than in areas in the same latitude range along the proposed route and in more remote parts of the region crossed by the Fort Yukon Corridor.

Environmental Noise

The general discussion of environmental noise along the proposed route (see Section 2.1.2.15) is applicable as well to the Fort Yukon Corridor. For much of its length the Fort Yukon Corridor is probably similar in ambient sound levels to the part of the proposed route south of about 59° N latitude. Between Watson Lake and the vicinity of Grande Prairie (Figure 8.1.2.4-3) where the corridor is occupied also by the Alaska Highway and related roads, ambient sound levels might be somewhat higher than along most of the proposed route because of the concentration of traffic on these roads. Other parts of the Fort Yukon Corridor that are lacking highways, such as west of Dawson, between Pelly Crossing and Faro, and between the mouth of Hoole River and the crossing of Frances River (see Figure 8.1.2.4-1), would probably be more similar in ambient sound levels to the part of the proposed route north of 59° N latitude where ambient sound levels are extremely low.

Evaluation of the Environmental Impacts

Climate

The discussion of possible impacts on climate along the proposed route (Section 3.1.2.1) is applicable to possible impacts along the Fort Yukon Corridor. The only impact on climate would be local and transitory ice fog.

The impact of climate on a pipeline in the Fort Yukon Corridor would be the same in general as on a pipeline along the proposed route (see Section 3.1.2.1), including the Interior Route (Section 8.1.2.1). Avoidance of the Prudhoe Bay Supply Line along the Beaufort Sea coast would eliminate the effects of the foggy maritime summer climate and drifting sea ice. The greater mileage of right-of-way through mountains would increase the hazards of flying both during construction and operations. The difficulties of construction in mountains would be further compounded by the greater distances that would be traversed, and the numbers of facilities to be built, in the intensely cold subarctic climate (see Section 8.1.2.9)

South of 65° N latitude, in areas of conventional winter or summer construction, the impact of climate on pipeline construction and operation would be the same as at equivalent latitudes on the proposed route.

Topography

The environmental impacts affecting topography are described in the following section under "Geology."

Geology

The terrain along the Canadian segment of the Fort Yukon Corridor and the areas subject to landsliding and slope-stability problems are summarized in Table 8.1.2.9-11; hydrologic features that would be affected by a pipeline along the Fort Yukon Corridor are summarized on Table 8.1.2.9-10; and permafrost problem areas are summarized on Table 8.1.2.9-11. The text that follows will merely emphasize the more unique aspects of different segments of the corridor.

The entire Fort Yukon Corridor lies within a region of long, cold winters, and permafrost is present in at least local areas everywhere except along the southernmost 225 miles of the 1200-mile Canadian segment. Almost the whole route of the corridor lies in steep or rolling terrain, and only 260 miles of the 1,200-mile Canadian segment is classified as "flat". One of the widespread environmental impacts of a cold pipeline in this cold climate and in this region of rolling and steep terrain, will be the widespread development of "slope icings" where obstructed soil drainage would seep to the surface to create accumulations of thick ice that could persisted through much of the summer, causing considerable changes in the vegetation and areas of hazardous footing.

In contrast to the proposed, Interior, and Cross-Delta Routes, the Applicant has not furnished specific information on alignments, construction schedules, numbers or locations of facilities in those parts of the Fort Yukon Corridor northwest of its junction with the proposed route. The absence of these data limits this impact analysis to general rather than specific comments. In the following discussions, it is assumed that (1) existing roads and material sites would be utilized wherever possible; (2) any pipeline would be located along the most favorable terrain within the corridor; (3) good engineering practice would be followed in all construction and maintenance operations; and (4) the impact of construction would be generally comparable to that of an oil pipeline.

Alaska-Yukon Border to North Klondike River--The westernmost 30-mile segment of the Fort Yukon Corridor crosses steeply dissected terrain carved in soft Tertiary sandstone and shale. The terrain is vulnerable to accelerated erosion and badland development upon disturbance of the vegetation. Ditching for a pipeline could locally undercut steep slopes and lead to accelerated landsliding. The steep slopes in this reach are susceptible to landsliding. Installation of a buried cold pipeline would induce development of a cylinder of frozen ground which would inhibit subsurface drainage and heighten the susceptibility to landsliding. Development of borrow pits in this reach might cause siltation in many minor streams crossed by the corridor but would not appreciably increase the turbidity of the Yukon River, which already carries a heavy suspended sediment load.

For several miles, the corridor lies on the flood plain of the Yukon River, where the risk of exposure and rupture of a pipeline during flooding would be high. Thus the risk of adverse effects from released gas would be higher on the Yukon River flood plain than elsewhere.

Another 6-mile stretch of the corridor lying about 30 miles east of the North Klondike River crosses a moderate slope developed on slumped Tertiary clays and sandstones. Disruption of drainage due to trenching and installation of a cold pipeline would heighten the landslide susceptibility of this area and also cause slope icings.

Many small areas of ice-rich permafrost are present in the western 50 miles of this corridor.

The seismic risk is low but not negligible in this segment. Only a few earthquakes of low magnitude have been identified in or near this portion of the Tintina Trench, but until a few years ago, the seismic network was inadequate to locate earthquake epicenters in Yukon Territory with the precision needed to evaluate seismic risk. Faults recognized along the Tintina Trench are thought to have undergone most of their movement tens of millions of years ago, but small movements have been recognized as having taken place within the last 1 or 2 million years (Hughes, 1970). However, the chances of active fault movement during any 20-year period are very small.

Richards Island to Campbell Lake--This segment of the Richards Island Supply Line coincides with a portion of the proposed route. Its environmental impacts are discussed in Section 3.1.2.3.

Campbell Lake to North Klondike River--Sand and gravel are readily available within the valleys of Blackstone and North Klondike Rivers, which extend through the southern 75 miles of the potential supply line corridor. As mapped by Vernon and Hughes (1966), these deposits are present in modern stream flood plains, alluvial fans, and alluvial terraces of both rivers. Environmental impact resulting from use of these materials would probably be minor, especially where borrow pits were located on outwash terraces of late Wisconsin age. Older terrace and fan deposits may lie beneath relatively thick silty overburden which, especially where frozen and ice-rich, would cause problems of spoil stability and stream siltation. The use of borrow pits located on the narrow modern flood plain of either river would be likely to cause siltation in active stream channels.

Farther north along the Richards Island Supply Line, lack of detailed geologic mapping precludes an exact assessment of the availability of construction materials or environmental problems that might result from their use. Within the Anderson Plain, sand and gravel may be readily available in the outwash deposits which reportedly blanket much of the area. The Peel Plain may contain less extensive near-surface outwash, but the corridor here crosses modern channels and flood plains of the Mackenzie and Peel Rivers where sand and gravel may be abundant.

Sand and gravel supplies within the Peel Plateau are uncertain, and the Cretaceous sedimentary rocks which underlie this province probably would be poor sources of crushed stone. Future detailed mapping may show fairly abundant water-washed glaciofluvial deposits along some parts of the corridor. If present, these would be the best sources of sand and gravel.

Within the Richardson Mountains, availability of construction materials would depend on the route adopted. The low pass at the head of Rock River may have been a glacial meltwater conduit, so extensive sand and gravel supplies could be present in this area.

Farther south, within Eagle Plain and the northern Ogilvie Mountains, the corridor generally follows bedrock ridges where sand and gravel would be unavailable. Cretaceous sandstones, which crop out in the Eagle Plain, might be acceptable sources of crushed rock. The abundant limestone in the northern Ogilvie Mountains would probably be fully satisfactory for construction purposes. Both the sandstone and the limestone occur interbedded with shales, which could cause such problems as instability of quarry walls, large unstable spoil piles, and siltation of streams.

Potential drainage disruption is greatest along the northern 100 miles of the supply-line corridor, which crosses the Anderson and Peel Plains at right angles to regional drainage. About 40 stream crossings are shown here on 1:250,000 scale topographic maps of the Canadian Department of Mines and Technical Map Surveys, and many additional smaller crossings must be present.

The supply-line corridor parallels rather than crosses most streams in the Peel Plateau and the Richardson Mountains, hence drainage disruptions probably would not be widespread or severe here. Local problems might occur, but these cannot be assessed without additional data on possible alignment selection and surficial geology.

Through the Eagle Plain, the corridor follows the divide between the Porcupine and Peel River watersheds, so the possibility of drainage disruptions should be negligible.

Within the northern Ogilvie Mountains, the supply-line corridor crosses a series of minor streams tributary to the Peel, Ogilvie, and Blackstone Rivers. Some environmental problems could occur, especially where stream crossings would be near slope bases within thick, ice-rich, frozen solifluction deposits.

No major stream crossings of the Blackstone and North Klondike Rivers would be necessary. Crossings of small streams would be in coarse gravel deposits of alluvial fans or outwash terraces. The greatest potential problems along this sector are where valley floors are narrow and almost entirely occupied by active modern flood plains. This seriously restricts the areas available for pipeline construction, and could create hazards such as (1) bank erosion and flood threats, (2) stream siltation resulting from construction and maintenance operations, and (3) discharge of other pollutants to drainage systems.

In general, near-surface, ice-rich permafrost is most widespread in the Anderson and Peel Plains within about 100 miles of Inuvik (Table 8.1.2.9-13). Low ground temperatures here should inhibit thaw, however, and the general flatness of the terrain should prevent severe slope erosion if a pipeline were constructed in the supply-line corridor. Differential subsidence over ice wedges or other massive ground-ice bodies could endanger a pipeline or other structures. An additional problem would be the alignment of the route across regional drainage. The corridor repeatedly crosses relatively wet, ice-rich swales and valley bottoms and traverses sloping terrace faces and stream banks.

Within the Peel Plateau and the Richardson Mountains (70 miles), steeper terrain would increase the likelihood of gullying, soil flowage, and other slope processes associated with thaw of ice-rich, fine-grained sediments. A pipeline alignment probably could follow gravelly stream beds through 30-50 percent of this region, however, greatly reducing the areas of potentially unstable terrain to be crossed.

Across the Eagle Plain, the ridge system followed by the corridor should provide relatively secure foundation for structures. Thermal erosion of shallow silt deposits might occur in places, but underlying bedrock may be close to the surface in most areas.

Although the supply-line corridor generally follows coarse gravels through the Ogilvie Mountains, local sites such as kettle fillings on old outwash surfaces would contain fine-grained ice-rich deposits. Careful routing should enable most of these areas to be avoided.

Accelerated erosion and mass wasting are likely to occur at many places along this corridor segment, especially in the follow situations:

1) Ice-rich, fine-grained, frozen sediments in the Anderson and Peel Plains, where areas of special concern would include low-lying wet sites and localities with high frequency of drainage lines crossing the corridor.

2) Flanks of steep stream incisions within the Peel Plateau, where areas of special concern would include slopes underlain by shale and those capped with clayey or silty drift.

3) Higher and steeper parts of the Richardson Mountains.

4) Solifluction slopes of the unglaciated northern Ogilvie Mountains.

5) Steep walls of glacial and fault-line valleys farther south in the Ogilvie Mountains, particularly those immediately south of North Klondike Pass.

North Klondike River to Pelly Crossing--This segment of the corridor crosses the Klondike, McQuesten, and Stewart Rivers, all major streams. All carry a heavy load of suspended sediment, so that siltation due to construction activities would have little impact upon their regime.

Three miles of the corridor extend along steep bluffs of the Stewart River and these are susceptible to gullying and landsliding. Disruption of drainage by stripping and trenching and by the frozen cylinder formed by operation of a cold pipeline would heighten landslide susceptibility and erodibility.

As much as 10 miles of a pipeline within the corridor would lie along the flood plain of the Stewart River and at least 2 miles would lie along the flood plains of smaller streams. In these areas, a pipeline would be vulnerable to rupture and thus these areas would be potential foci for the adverse effects of suddenly released gas. The pipeline and its surrounding frozen cylinder of sediment would constrain the tendency of the stream to erode its banks and to migrate across its flood plain.

The 30 miles of corridor between North Klondike River and McQuesten crosses areas mantled with thick peat, silt and muck, which are perennially frozen and rich in ice. Excavation of borrow pits here would require removal of as much as several tens of feet of frozen overburden which would have to be stacked elsewhere upon the landscape. Subsidence and liquefaction can be expected wherever the vegetation is stripped and also in areas where dark-colored spoil is dumped upon the vegetated surface.

Seismic risk is low but not negligible in this segment of the Fort Yukon Corridor. Evidence for fault-disturbance of Pleistocene deposits noted by Hughes (1970) indicates that movements have taken place within the last 1 or 2 million years. However, the chances of active fault movement during any 20-year period are very small.

Pelly Crossing to Watson Lake--Nearly 50 miles of the Pelly Crossing-Watson Lake section crosses slopes steeper than 10 percent and for 42 miles the corridor lies at the base of steep mountain slopes in the Pelly Mountains and Simpson Range. Mountain peaks rise 2,000 feet or more above the possible alignment. These are extremely active slopes, subject to frequent snowslides, avalanches, and rockfalls. Trenching for a pipeline would undercut steep slopes and operation of a cold pipeline would disrupt subsurface drainage, enhancing the susceptibility of these areas to gullying, avalanching, and rockfall.

The corridor crosses the Pelly River at Granite Canyon, a deeply incised reach carved in Tertiary basalt and soft Tertiary sedimentary rocks. Construction of a pipeline would channelize drainage and lead to severe gullying. A pipeline would have a similar impact at crossings of several deeply incised southern tributaries to the Pelly River between Harvey Creek and Black River; it would follow the incised valley of the Pelly River for many tens of miles eastward from Harvey Creek and it would also lie near the courses of the Hoole, Black, and Liard Rivers for short distances. Construction of a pipeline and erosion of the exposed spoil would add silt to these large rivers but the impact would be small since they carry a heavy suspended load in their natural state.

A pipeline would lie on the actual flood plain of the Pelly River for about 10 miles and on the flood plains of the Hoole, Black, and Liard Rivers for shorter distances. Disruption of the pipeline by channel migration, damage from occasional flooding (especially spring ice-jam floods), and diversion of floodwaters by the pipeline grade would be potential hazards in these reaches.

Two moderately strong earthquake epicenters were reported in the southern part of the Liard Plain in 1965 and 1966 (LeBlanc and Wetmiller, 1974). Seismic risk is thus somewhat greater than in other sections of the Fort Yukon Corridor.

Watson Lake to Muskwa River--Stream crossings are major problem areas and thus areas of major potential environmental impact in this section of the corridor. The swift and deeply incised Liard River would be crossed near Liard Hot Springs. Excavations associated with the crossing would create areas vulnerable to severe gullying and landsliding. In the Rocky

Mountains the corridor crosses the wide braided flood plains of McDonald Creek and the Tetsa River. If a pipeline were placed underground here, the cylinder of frozen ground would disrupt underflow and heighten the tendency to form extensive flood plain icings.

Trenching and stripping of the steep river bluffs that extend about 10 miles northwest from Liard Hot Springs and operation of a cold pipeline on the site would disrupt subsurface drainage and increase the susceptibility of the area to large-scale slow landsliding. In the Rocky Mountains, the corridor skirts the base of steep slopes rising several thousand feet above it and a total of 42 miles of the corridor is vulnerable to avalanches, rockfalls, and landslides. Undercutting for construction of a pipeline would heighten the vulnerability of this area to catastrophic mass-movements. Another 15-mile stretch near the Muskwa River crosses steep ridges carved in Cretaceous shale; steepening of slopes due to trenching, gullying along a pipeline alignment, and disruption of drainage by the frozen cylinder of soil around a pipeline would greatly increase the landslide hazard in this stretch.

The corridor skirts Muncho Lake, a clear-water lake, for about 6 miles; construction activity, trenching, and development of borrow pits would add greatly to the sediment delivered to the lake and temporarily impair the clarity of the water.

Muskwa River to Windfall, Alberta--The southernmost 450 miles of the Fort Yukon Corridor passes through a region of Cretaceous shales and minor sandstones covered, for the most part, with a thin mantle of glacial drift. Granular materials for construction of roads, airfields, pumping-station pads and backfill in the pipeline trench are scarce and construction of a pipeline through this area would seriously deplete the supply.

Large-scale, slow landslides, some ancient and some still active, are widely distributed on slopes underlain by the Cretaceous shale. Some 225 miles of the Fort Yukon Corridor crosses these slide-susceptible slopes between Muskwa River and the junction with the proposed route. Disturbance of natural drainage by construction activities and by operation of a cold pipeline would enhance the tendency for landslides to develop, reactivating some old slides and causing some new ones. The crossings of deeply entrenched rivers such as the Peace, the Wapiti, the Athabasca, and the Smoky Rivers would be especially serious foci of difficulties. The valley walls of these rivers are carved largely in landslide-prone glaciolacustrine silt; excavation and surface disturbance during installation of a pipeline would greatly heighten the landslide susceptibility in these areas.

Mineral Resources

Metallic and Nonmetallic Mineral Resources--Other than the consumptive use of construction materials, the construction and operation of a gas pipeline in the Fort Yukon Corridor, including a corridor for the supply line from Richards Island, would have no impact on metallic or nonmetallic mineral resources. The area is served or will be served by existing and planned transportation facilities, so the additional accessibility that might be offered by a pipeline and its appurtenances would be minimal.

Soils

Trenching and other pipeline construction activities would impact topsoils along the Fort Yukon Corridor to a variable degree ranging from complete destruction to partial burial by addition of thin layers of excavated subsoils and soil parent material. In addition, there would be extensive mixing of topsoils with low-nutrient subsoils and parent material from the pipeline trench. Because most subsoil and underlying geologic materials likely to be excavated generally are not well-suited for plant growth, revegetation measures might have to be repeated several times before successful plant growth and ground stabilization could be obtained. The British Columbia Soil Survey (Kelley and Sprout, 1956) has experienced difficulties with revegetation of disturbed areas and recommends that steep grading be avoided in order not to expose infertile subsoils.

A potential for wind erosion and water erosion of soils that would be exposed during construction exists along the entire corridor. In permafrost areas disturbance of some soils during construction might, in conjunction with differential thawing of permafrost, cause a decrease in terrain stability and a ponding and channeling of surface waters. In non-permafrost areas, disturbance of topsoils might alter surface drainage and increase erosion; locally, dessication of topsoils might occur.

Water Resources

Throughout its length, the Fort Yukon Corridor crosses about 71 major stream channels and 942 minor streams (see Table 8.1.2.9-10). The degree of potential impact would depend upon the design and the measures taken during construction to minimize the impact. Four areas of concern are: (1) channel erosion, (2) icings, (3) depletion of streamflow during construction, and (4) drainage disruption (see Table 3.1.2.5-1 for a general summary of impact mechanisms and possible consequence).

The primary impact on ground water would be the disturbance of the shallow active layer overlying permafrost during pipeline construction and operation (see Figure 3.1.2.5-1b). Disturbance of the thermal regime in the active layer would create new ground-water flow patterns resulting in aufeis, accelerated thermal degradation, accelerated erosion, frost heaving, and possible explosive icing mounds. Another potential for impact on ground water would be the discharge of liquid wastes and leaching of sanitary landfills.

Vegetation

The Fort Yukon Corridor (Figures 8.1.2-1; 8.1.2.4-1, 2, and 3) would be about 97 miles longer than the proposed route in Canada and would traverse more mountainous terrain and more extensive areas of permafrost, especially within the discontinous permafrost zone. Increased length of right-of-way, greater number of compressor stations, larger requirement for gravel borrow, and more space for ancillary facilities, all would have direct impact on the amount of vegetation removed or disturbed. The corridor would, however, avoid the proposed route crossing of the Yukon Coastal Plain, a tundra resource of limited supply.

The types of impact resulting from construction, operation and maintenance of a pipeline in the Fort Yukon Corridor would generally be the same as those discussed for the proposed route (Section 3.1.2.6) and the Interior Route (Section 8.1.2.1).

Wilderness and Ecological Reserves

Comments regarding effects on wilderness and its vegetation component as stated for the proposed route (Section 3.1.2.6) are applicable to the Fort Yukon Corridor. This corridor avoids the wilderness of the Herbaceous Coastal Tundra, but throughout the Yukon interior traverses Forest-Tundra and Boreal Forest that is of wilderness or near-wilderness quality. The Dempster Highway, which the corridor follows, is, however, the first major opening of the northwestern Yukon wilderness and the Alaska Highway has been in existence for more than 3 decades.

CAGPL (1974e, 1.5.3.2, p. 31) states, "The International Biological Program has proposed reserve areas in the Dawson Range, in the Ogilvie Mountains and along the Yukon River. Other areas proposed as Arctic ecological reserves occur in the southern Mackenzie Delta, the Caribou Hills, and the Dolomite Lake-Campbell Lake area. Nine of these sites were definitely set aside in 1971." The impact on Wilderness and Ecological Reserves would be some loss or diminished quality of vegetation and the ecosystems of which it is a component. Although the amount of land used is relatively small, the corridor would potentially be in conflict with the objective of the IBP to maintain the Ecological Reserves in their natural state.

The Applicant states, with reference to the corridor from the Alaska-Yukon border to Pelly Crossing, "Much of the terrain between the border and Pelly Crossing was unglaciated during the Wisconsin glaciation. As a result there is a greater probability of finding endemic populations of rare plant species. This unglaciated region extends northward, including the pipeline segment from the Richardson Mountains southwards to Dawson."

Endangered Plant Species

There is the possibility of rare endemics being endangered by the construction of a pipeline in this corridor. The nature and magnitude of the threat could only be determined by detailed field work prior to selection of a specific pipeline alignment.

Corridor Segment Impacts

Richards Island to Fort McPherson--The potential impact on this general area was discussed in Section 3.1.2.6.

Fort McPherson to North Klondike River--The principal impacts east of the Richardson Mountains would be the streambank removal of mature riverbank spruce forest and tall shrub communities at stream crossings; slope instabilities and loss of vegetation in all grading operations; possible increase in incidence of fire; and, most importantly, the degradation of permafrost through interference with the natural thermal balance maintained by the moss-peat mat. The crossing of the Richardson Mountains would have no major impact on Forest-Tundra, Low-Shrub Heath, or the Alpine Tundra communities other than the losses by vegetation removal on the ditch line or clearing of trees from the right-of-way. All activities entailing travel off the right-of-way would be destructive of vegetation and initiate thermal erosion throughout this area, except at the higher elevations of the Alpine Tundra.

North Klondike River to Pelly Crossing--This portion of the corridor closely follows the Klondike Highway across low, rolling terrain. The area is in discontinuous permafrost and preservation of organic mat and vegetation is essential. The principal impact on vegetation would be the loss by removal of spruce forest which, in this area, is best developed on lower slopes above the entrenched rivers. The impact on valley bottoms would be on tall shrub communities. Endemic species could be affected in this area, as previously mentioned.

Pelly Crossing to Watson Lake--This corridor would follow the Pelly and Liard River valleys to Watson Lake. The impact of the corridor would be on the most productive spruce forests, which occupy the broad alluvial flats, and black spruce and lodgepole pine forests above the flood plains. No community type would be affected in a major way although the visual scar, as in all forests, would mar the spruce and pine forests for the duration of the project.

Watson Lake to Windfall--This area is in the southern fringe of discontinuous permafrost and there would be decreasing concern for slope instabilities. The probability of summer construction in the area to the intersection with the proposed route could result in temporary but severe erosion problems at stream crossings and destruction of riparian vegetation. The principal impact on vegetation would be the clearing of the right-of-way through the spruce, lodgepole pine and alpine fir forests. Increased aridity southward into the Aspen Parkland would maintain susceptibility to fire characteristic of the entire corridor. The lower density of forests would, however, somewhat reduce the capability to carry large fires.

In the area of Fort St. John and Grande Prairie, former grassland is under cultivation or devoted to grazing. In these areas, the impact of pipeline construction would be the temporary interference with farming activities as previously discussed (Section 3.1.2.6).

Major Plant Communities Affected

The impacts on vegetation are treated only for the 1,692 miles of the corridor to Windfall, Alberta. This segment represents 67 percent of the total corridor to the delivery points at the Canada-U.S. border. The location of the right-of-way and related facilities is not known and it is possible only to approximate the acreages of plant communities that would be affected. The corridor crosses Low Shrub-Heath Tundra, Alpine Tundra, Forest-Tundra, Boreal Forest, and small areas of Aspen Parkland. Excluding the Richards Island Supply Line, the corridor, from the Alaska-Yukon border to Windfall, lies entirely within the Boreal Forest, excepting the crossings of outlying areas of Aspen Parkland in British Columbia and Alberta. Based upon average figures for the total corridor (Table 8.1.2.9-1), the acreages of vegetation affected on the segment ending at Windfall would be approximately as follows:

	Right-of-way	Facilities	Total
Low Shrub-Heath Tundra	1,269	286	1,555
Alpine Tundra	1,804	408	2,212
Forest-Tundra	3,564	804	4,368
Boreal Forest	17,197	3,881	21,078
Aspen Parkland	577	130	707
Total	24,411	5,509	29,920

The foregoing figures for major plant communities reflect a large increase in the area of alpine tundra vegetation that would be affected, in comparison to the proposed route. This reflects the increased amount of mountainous terrain crossed by the Fort Yukon Corridor and inclusion of the total transect of the Alpine Tundra Formation without knowledge of the specific altitude and alignment of a route. Thus, 35 miles in the Richardson Mountains and 90 miles in the Ogilvie Mountains are designated as corridor crossings of alpine tundra vegetation. The actual pipeline route would certainly follow stream valleys at lower altitudes, as much as possible, with consequent lesser effects on alpine tundra and greater impact on shrub and tree communities. The specific differentiation of such communities cannot be made for the corridor.

Wildlife

Fish

Because of the rugged terrain, steep-gradient streams, and potentially long stretches of side-slope alignment a pipeline following the Fort Yukon Corridor would likely cause more turbidity and siltation than one along the proposed route.

Its greater length (about 100 miles longer than the proposed route) and its traverse through large wilderness areas suggests that it would have large impact on fish and fish habitats. In the absence of substantial information it can only be assumed that the types and magnitudes of impacts would generally be the same as for similar watersheds and geographic areas of the proposed route.

Mammals and Birds

Alaska-Yukon Border to North Klondike River--In addition to over 2.8 square miles of terrestrial mammal habitat lost to disturbance there would be a wider zone of influence, particularly on larger species, due to new human access. Crossing this area would likely result in reduction in numbers of some species, including the wolverine. There is also a potential for interfering with movements of caribou, but as the corridor is reported to follow the boundary between the Porcupine and Fortymile herds, its use would not be expected to have any adverse effect other than a slight encroachment on herd ranges. In the more rugged terrain the corridor is near mineral licks considered to be critical habitat for Dall sheep. Human disturbance rather than destruction of habitat would be the major concern.

The area is not a productive one for waterfowl, so no adverse impacts on populations of ducks and geese would be anticipated. Peregrine falcons have been observed in the area in the past, but no nesting sites have been identified. Other raptors undoubtedly occur and some disturbance to them would be likely. Loss and alteration of some Boreal-Forest bird habitat would occur, but would not adversely affect the populations, which are widely distributed. Local changes would result in the reduction of some species, but eventually a new increase of birds (all species) might well occur because of the diversification of habitats brought about by pipeline construction.

Campbell Lake to North Klondike River--This is a 383-mile corridor from Richards Island to its junction with the main corridor. A pipeline in this corridor segment would generally be parallel to and very close to the Dempster Highway.

A major concern is the possibility that migration of the Porcupine caribou herd would be deflected or turned back from a considerable area of winter range in the Peel River drainage because of disruption by pipeline construction and operation added to that caused by traffic on and development along the Dempster Highway. Loss of this winter range would be followed by reduction of the herd. Impacts on other mammals would be similar to those discussed under the Interior Route (Section 8.1.2.1). Reduction of wolves, grizzly bear, and wolverine could follow the highway and pipeline construction.

The species of birds present and the impacts on them would be similar to those described for the Interior Route (Section 8.1.2.1). Waterfowl would be affected most between Inuvik and Fort McPherson, and possibly in areas such as the Eagle River valley where abundant waterfowl have been reported. Impacts on raptors, including the endangered peregrine falcon, is to be expected. Peregrine falcons, which are susceptible to disturbance within distances greater than a mile from eyries, are known to occur in the vicinity of Campbell Lake near Inuvik and have been seen at the Peel River crossing; they nest along the Ogilvie River.

North Klondike River to Pelly Crossing--This segment is common to the Fort Yukon and Fairbanks Corridors. Approximately 79 of the 113 miles closely parallel an existing highway.

In most instances, impacts on mammals would be greater where the corridor departs from the highway. Some increased human access resulting from construction would be expected to increase trapping pressure on apparently good populations of furbearers in this area. No important impact other than a temporary loss of some terrestrial habitat for small mammals which constitute the prey for some furbearers is to be expected.

In addition to the general changes in habitat discussed in the evaluation of impacts in the Yukon-Alaska boundary to mouth of North Klondike River segment of this corridor, one potential adverse impact on birds is identified. This is increased disturbance of large numbers of migrating sandhill cranes that use the open flats and sandbars of the Stewart River. Because this river offers better habitat than the Klondike River, somewhat greater potential for impacts on other waterfowl also exists.

Pelly Crossing to Watson Lake--This segment does not parallel existing transportation facilities as closely as does the rest of the Fort Yukon Corridor in Canada. It crosses the heavily traveled highway from the Anvil Mines near Faro to Carmacks and the Canol Road near Ross River.

Increased accessibility resulting from pipeline construction and operation would increase hunting and trapping pressures on grizzly bear, large herbivores, including stone sheep and moose, and on smaller furbearers, including beaver, muskrat, and marten. The main impacts would be some minor loss of habitat for small terrestrial mammals lower in the food chain than the furbearers and possible damage to aquatic mammals from fuel spills that might enter waterways.

As birds are less common in this segment than in most other parts of the Fort Yukon Corridor, no significant impacts on birds are to be expected.

Watson Lake to Windfall--Most of this segment is generally parallel to the Alaska Highway. However, between Summit Lake and Trutch the corridor leaves the highway and traverses about 85 miles of rugged terrain in the Muskwa mountain range.

Important populations of large herbivores along this route include mountain goat, stone sheep, moose, and mule and white-tailed deer. In the Muskwa Range impacts expected would involve disturbance and perhaps a temporary loss of some forage production area. No critical habitats are identified except those for mule deer and moose in the Stoddart, St. John Creek, and Peace River valleys where some undetermined amount of critical winter range would be affected in an area where a relatively high density of moose is reported. There would be some loss of habitat in the 55-mile stretch along the Muskwa River but the greatest impact would be from the increased frequency of vehicle-moose collisions and, perhaps, increased problems with animals falling into ditches during the construction period.

As in other sections of the Fort Yukon Corridor, losses and modification of bird habitats would occur. The numbers of birds affected would be greatest and the adverse impacts would persist longest in streamside or riparian areas in the parts of this segment where clearing would not result in creating more productive habitats through diversification.

Other segments of this corridor are identical to the proposed route, the potential impacts of which are discussed in Section 3.1.2.7.

Ecological Considerations

The general nature of impacts of the proposed pipeline on ecosystems has been discussed for the proposed route (section 3.1.2.8) and all comments apply to the Fort Yukon Corridor.

Economic Factors

If a pipeline were built along the Fort Yukon Corridor, the route distance in Canada would be only about 100 miles longer than along the proposed route. Therefore, the amounts of labor and time required would generate about the same amount of total economic activity as would construction of the proposed route. In the operational phase the location close to populated areas and established highway routes might attract a stable staff from the local residents and result in a moderate stimulus to the relatively well-developed infrastructure and secondary employment sector.

Economic activity related to oil and gas exploration in the Mackenzie region would be expected to decline, perhaps very significantly, if the pipeline were laid in the Fort Yukon Corridor far from the regions having gas potential. In this projected case, a long branch line would be needed to bring gas from the Mackenzie Delta region and this line would place the proposed junction in central Yukon Territory near Dawson instead of in northwestern N.W.T. near Inuvik.

Building a natural-gas pipeline in this corridor might, if economically practical, offer a fuel supply through short branch lines to the various established communities. The Applicant's study indicates that the possible easy availability of gas fuel would have little impact on the location or development of smelter operations in the mining areas along the corridor.

The availability of natural gas could be a factor in development of a kraft pulp mill, but the low per-acre yield of timber and high transportation costs for finished products would probably offset the favorable fuel factor. The impact of gas fuel on development of a sawmill and wood products industry would be negligible because of the relatively small energy needs.

Other existing economic activities in the Fort Yukon Corridor would be expected to continue with some expansion as a result of the increase in personnel and cash flow that would result from pipeline construction and operation. The level of activity in the mining sector would be expected to function independently of any pipeline operations.

Employment and income for the project would be essentially the same as has been described for the proposed route. Each route offers the potential of maximizing regional employment in terms of the available regional labor supply. The currently unemployed available potential labor force within the corridor area is quite small, probably only a few hundred. It should be noted that in terms of total employment in the North, the potential labor requirements for gas field exploration, development, and operations far exceed those that would be associated with pipeline operations and maintenance in the post-construction phase.

No specific information on the local tax structure and base is offered. It is assumed that any pipeline development in this alternative corridor would enlarge the tax base and revenues.

Sociological Factors

The current (circa 1973) population of approximately 4,100 in the area of the Fort Yukon Corridor is distributed as follows: Clinton Creek about 400, Dawson 745, Elsa 480, Mayo 462, Stewart Crossing 43, Pelly Crossing 274, Ross River 317, Faro 850, and Watson Lake 553. No projection of the population trend is offered by the Applicant. It seems reasonable to assume that if a pipeline were built in this corridor a relatively small overall net increase might be generated. The future activities in the fields of tourism, sport fishing and hunting, and mining would probably have the more significant impact on the population trend throughout this region.

Community structure in terms of government, housing, and services would be expected to undergo changes commensurate with a modest population growth and demands for more modern facilities. The impact of a pipeline would probably provide a temporary stimulus during the construction phase; during the operation phase the impact probably would be localized in communities close to compressor stations and maintenance bases. The overall impact of pipeline construction and operation probably would be similar to that along the other routes and corridors.

Land Use

The discussion of possible impacts along and near the northern part of the proposed route (Section 3.1.2.11) is also applicable to possible impacts on land use in the area traversed by the Fort Yukon Corridor and the Richards Island Supply Line. Activities during the construction phase of the project might cause some changes in the migration patterns of the Porcupine caribou herd, thereby affecting normal hunting patterns of those people dependent on these animals for subsistence.

Archeological and Historic Values

Lack of adequate information on archeological and historical sites and resources of the Fort Yukon Corridor makes it difficult to predict the impact of possible pipeline construction on such sites and resources. Obviously, all phases of construction involving land use could cause loss of, or damage to, archeological and historical resources, which by their nature, are very limited and irreplaceable. Construction of ancillary features such as compressor stations, borrow pits, and stockpile sites, as well as the excavation of a pipeline trench itself, could destroy potential archeological and historic sites.

Construction of a pipeline in the Fort Yukon Corridor might provide archeologists increased access to archeological sites in the sections where it would not parallel an existing roadway (Eagle to Dawson, Pelly Crossing to Watson Lake), but making access easier for the general public might also prove destructive to such now-protected sites.

While construction of the pipeline could destroy potential archeological sites, it could also uncover some sites, provided proper salvage measures were undertaken. Any new information thus obtained would probably contribute greatly to knowledge of the prehistoric inhabitants of the region.

Recreation and Esthetic Resources

Construction of a buried gas pipeline along the Fort Yukon Corridor would create an unbroken 120-foot-wide clearcut swath through the Boreal Forest. In areas of rough terrain, extensive sidehill cutting in rock and other disturbances to the natural contours of the landscape would be required. Where portions of the Fort Yukon Corridor roughly parallel existing or planned highways, these disruptions in the landscape would have much visual impact on motorists, especially those interested in sightseeing and photography. Auxilliary construction features such as borrow pits and compressor stations would also mar the scenery.

The effect of pipeline construction on the three Provincial parks in northern British Columbia (Liard River Hotsprings, Muncho Lake, and Stone Mountain) would probably be mainly visual, although some facilities could be disrupted, depending on the exact pipeline location selected. Also, congestion of roads and tourist facilities might occur here and elsewhere along the corridor during summer construction periods.

The impact on game animals, fish, and birds is discussed elsewhere in this volume (see preceding section on Wildlife). Where a pipeline in this corridor would follow existing or planned roads, it would have little impact on wilderness values. It could eliminate some potential campsites for highway travelers, however, and additional short-term loss of recreation quality would occur in the immediate vicinity of construction activity owing to noise, smoke, and dust. Compressor stations could have an adverse impact in the form of noise and possible air pollution.

Air Quality

Construction and operation of a gas pipeline in the Fort Yukon Corridor would have the same types of impacts on air quality as if the proposed route were followed (Section 3.1.2.14). In most of the corridor, pollutants from internal combustion engines used for pipeline construction, operation, and maintenance would be in addition to similar emissions from vehicles on highways and stationary sources in settlements and probably would not in themselves be obvious. All pollutants would probably be rapidly dispersed.

Environmental Noise

Noise emissions along the Fort Yukon Corridor would be generally similar to those along the proposed route, discussed in Section 3.1.2.15. However in parts of the corridor where it is occupied also by the Alaska Highway and related roads, the noise impact of constructing and operating a pipeline might be somewhat less than along much of the proposed route, because existing highway noise has already intruded upon the prior condition of very low noise levels. On the other hand, this part of the corridor also has a higher resident and transient population than many parts of the proposed route, and many of these people may find the added construction noise, and, locally, the noise of the continuously operating compressor stations during the operational phase, sufficiently annoying that these noises would constitute significant noise impacts.

The differences in the noise impact on wildlife between this route and the proposed route will be a result of the differences between the numbers and seasonal locations of wildlife along the two routes.

The Yukon River supports a major nesting area (about one nest per 10 miles) for peregrine falcons from the Alaska-Yukon border for 80 to 100 miles. Disturbance of these birds could occur from aircraft noise during pipeline surveillance flights (AAGPC, 1975b).

8.1.2.5 Fairbanks Corridor

The Fairbanks Corridor (Figure 8.1.2-1) extends southeastward from the Alaska-Yukon border at Beaver Creek and from Richards Island in the Mackenzie Delta to the proposed route at Milepost 1265, near Windfall, Alberta (Figures 8.1.2.4-2 and 3, 8.1.2.5-1 and 2). South of Windfall, the corridor is coincident with the proposed route (Section 2.1.2). Only the three segments of the corridor not coincident with other corridors are described here: 1) Alaska-Yukon border to Whitehorse, 270 miles; 2) Pelly Crossing to Whitehorse, 170 miles (Richards Island Supply Line); and 3) Whitehorse to Watson Lake, 260 miles.

The Watson Lake to Windfall and Campbell Lake to Pelly Crossing segments (Richards Island Supply Line) are coincident with the Fort Yukon Corridor and are described in Section 8.1.2.4. The Richards Island to Campbell Lake segment, 87 miles, is coincident with the proposed route and is discussed in Section 2.1.2.

Including the coincident parts of the proposed route, the corridor has a total length of 2,826 miles.

The Haines Option Corridor to the Fairbanks Corridor extends southward about 160 miles from Haines Junction to the coast at Haines, Alaska (Figure 8.1.2.5-3). It follows the Haines Highway along glaciated valleys of the Coast Mountains through Yukon Territory (65 miles), British Columbia (50 miles), and Alaska (45 miles).

Description of the Existing Environment

Climate

The climate of the area traversed by the Fairbanks Corridor is generally similar to that of the proposed route (Section 2.1.2.1) in the same latitude range, although temperature extremes are somewhat greater in western Yukon Territory than in the Mackenzie Valley.

Topography

A generalized topographic description of the Fairbanks Corridor is provided under "Physiography" in the following discussion of the geology of the corridor.

Geology

East of the Alaska-Yukon border, the Fairbanks Corridor follows the Alaska Highway southeastward 530 miles through Yukon Territory to Watson Lake where it merges with the Fort Yukon Corridor (Figure 8.1.2.5-1). Several geologic studies (Tempelman-Kluit, 1974; Muller, 1967; Kindle, 1953; Wheeler, 1961; Mulligan, 1963, Gabrielse, 1969; Lord, 1944) covering various parts of this region between the Alaska-Yukon border and Watson Lake were used to prepare the following description of the Fairbanks Corridor.

The available geologic maps of this region between Inuvik and Whitehorse are extremely generalized because very few detailed studies have been made, consequently, the description of this corridor deals with regional relations rather than specific details.

Physiography

Alaska-Yukon Border to Whitehorse--For 50 miles east of the Alaska-Yukon border, the Fairbanks Corridor extends south-southeast across the Yukon Plateau (Figure 8.1.2.5-1). The initial 10 miles, from the border to Snag Creek, traverses mainly unglaciated terrain of moderate relief which forms a low divide between the Tanana River drainage of Alaska and the White River drainage of Yukon Territory. The corridor rises gradually from about 1,850 feet at the border to about 2,100 feet at the divide, then descends to about 2,000 feet at Snag Creek. Valley floors are poorly drained and marshy, with probable thaw lakes evident in several places. The valleys are flanked by bedrock hills and ridges which rise to altitudes of 3,000 to 3,400 feet. South of Snag Creek, the corridor crosses the Wellesley Basin, a broad topographic depression in the Yukon Plateau (Bostock, 1948). The basin floor, between about 2,000 and 2,500 feet in altitude, is covered by poorly drained glacial deposits. A few isolated bedrock hills and ridges rise to heights of 1,000 feet or less above the basin floor. More extensive uplands along the south flank of the basin near White River reach altitudes as high as about 5,100 feet.

Near White River, the corridor enters the Shakwak Trench, a major topographic and structural feature, which it follows southeastward for about 130 miles to Haines Junction. The floor of the trench is only 3 to 4 miles wide near White River, but broadens progressively to the southeast. It ranges in width between 5 and 8 miles near Kluane Lake, and averages about 8 miles in width near Haines Junction. The trench is floored by glacial deposits throughout its length, and is veneered with extensive postglacial river and lake sediments at several localities. It is crossed by five large braided rivers (White, Donjek, Kluane, Slims, and Dezadeash) and is occupied for 35 miles by Kluane Lake. Smaller ponds and bogs are abundant in many segments of the trench, which total about one-third (45 miles) of its total length. The trench rises gradually in altitude from about 2,400 feet near White River to about 3,100 feet across an almost imperceptible divide at the southeast end of Kluane Lake. Altitudes decrease rapidly between Kluane Lake and Haines Junction, where the valley floor is about 2,000 feet above sea level. The trench is flanked to the southwest by the Kluane Ranges, which comprise the outermost ranges of the St. Elias Mountains. Precipitous slopes rise abruptly to altitudes of 6,500 to 7,500 feet in the ranges, and a few peaks are as much as 8,000 to 8,500 feet in altitude. Many of the higher peaks bear cirque glaciers and small valley glaciers. The ranges are segmented by a series of deep U-shaped valleys through which outlet glaciers from the St. Elias icefields formerly flowed north and northeast to fill the Shakwak Trench. North of the trench, gentler slopes rise to altitudes of 6,000 to 7,000 feet along the south flank of the Yukon Plateau. The plateau has relatively subdued relief, with mountain tops commonly flat or rounded, flanking slopes moderate in gradient, and low passes at the heads of many valleys.

Through the 90 miles between Haines Junction and Whitehorse, the corridor follows the Takhini Valley. This trough ranges in width between about 3 and 6 miles. Like the Shakwak Valley, it was subjected to intensive glaciation during late Pleistocene time. Glacial deposits underlie the entire valley floor, although they are covered in places by postglacial stream, lake, and eolian sediments. Eastward from Haines Junction, the valley floor rises gradually toward a low divide at an altitude of about 2,350 feet which separates the west-flowing Dezadeash River from the east-flowing Takhini River. It then descends to between 2,000 and 2,100 feet at Whitehorse. The Takhini Valley is flanked on the north by the Yukon Plateau, which rises to gently rounded uplands at altitudes of between about 5,000 and 6,500 feet. The valley lies in the Yukon Plateau, although a short segment east of the Dezadeash-Takhini divide is bordered by the northwest tip of the higher and more rugged Coast Mountains (Bostock, 1948). Several peaks in this area exceed 7,000 feet in altitude.

Richards Island to Campbell Lake--This part of the Richards Island Supply Line coincides with a portion of the proposed route. Its physiography is discussed in Section 2.1.2.3.

Campbell Lake to Pelly Crossing--This part of the Richards Island Supply Line coincides with the Fort Yukon Corridor. Its physiography is discussed in Section 8.1.2.4.

Pelly Crossing to Whitehorse--South of Pelly Crossing, the corridor for the Richards Island Supply Line extends southward about 170 miles to join the main segment of the Fairbanks Corridor at Whitehorse (Figure 8.1.2.5-2). Throughout this distance, it follows the Klondike Highway along a series of glaciated valleys which dissect the Yukon Plateau (Bostock, 1948). The entire region has been glaciated, and all but the northernmost 35 miles were ice covered during the late Wisconsin (Hughes and others, 1969).

Through the initial 20 miles between Pelly Crossing and Minto, the supply line would cross a range of low hills, follow a through-going glacial trough, and lie entirely below 2,000 feet altitude.

Beyond Minto, the line would follow the broad (2- to 3-mile-wide) valley floor of the Yukon River for 50 miles southward to Carmacks. Relief along this segment is negligible except where the Yukon River impinges against the east margin of its flood plain. At these localities, transportation lines are forced into the more rugged terrain of the Yukon Plateau which rises to maximum altitudes of about 4,500 feet on both sides of the valley here.

South of Carmacks, the supply line corridor follows the valley of Nordenskiold River, a tributary of the Yukon, then extends up the valley floor of Klusha Creek to a low divide 10 miles west of Lake Laberge. This 50-mile segment has little local relief along valley floors, and ascends in altitude less than 1,000 feet. Valleys are broad, ranging from about 2 miles wide near Carmacks to 1 to 2 miles wide along Klusha Creek and across the divide. Bordering uplands of the Yukon Plateau rise to maximum altitudes of 4,000 to 4,700 feet here.

The corridor continues southward 30 miles and intersects the Yukon Valley at the south end of Lake Laberge, then ascends the Yukon Valley 20 miles farther to Whitehorse. Valley floors remain wide, ranging from 1 to 2 miles between the divide and Lake Laberge to about 6 miles farther south. Local mountains and ranges within the Yukon Plateau here occasionally rise to altitudes as great as 6,800 feet.

Whitehorse to Watson Lake--Between Whitehorse and Johnsons Crossing, the corridor follows a series of glaciated valleys through the rolling to level-crested uplands of the Yukon Plateau. These uplands rise to altitudes of about 4,000 to 5,000 feet, but are as high as 5,500 to 6,000 feet in a few localities close to Teslin Lake. For 25 miles southeast from Whitehorse, the corridor follows the broad (3 to 4-mile-wide) floor of the Yukon River valley. The corridor skirts the north and northeast shores of Marsh Lake and follows a narrow valley across a low ice-scoured divide to the drainage basin of Teslin Lake. Gradients along this segment of the corridor commonly are gentle. The corridor rises from an altitude of about 2,100 feet near Whitehorse to slightly less than 3,000 feet at the divide between the Yukon and Teslin Drainages and descends to about 2,250 feet at Teslin Lake.

Along the northeast shore of Teslin Lake, the corridor occupies a narrow (less than 1/2-mile-wide) zone, possibly a lacustrine terrace, that extends along the flank of the Big Salmon Range. As the glacier-scoured valley wall rises to altitudes of about 4,500 to 5,000 feet here, this part of Teslin Valley has an average relief of about 2,500 feet.

From Teslin Lake to the Cassiar Mountains, the corridor traverses the Yukon Plateau, where broadly rolling uplands rise to altitudes of 3,000 to 5,000 feet. The uplands have been strongly dissected by glaciation; bedrock exposures are restricted to individual, generally small, upland masses separated by broad drift-filled valleys. The corridor rises from an altitude of about 2,250 feet at Teslin Lake to about 2,700 feet near the margin of the Cassiar Mountains.

Through the Cassiar Mountains, the corridor occupies a narrow 0.5 to 1.5-mile-wide), deeply scoured glacial valley flanked to the north and south by rugged uplands that commonly rise to altitudes of 6,000 to 7,000 feet. The uplands have been strongly sculptured by ice, and are segmented by numerous U-shaped troughs. The corridor follows the valley of Swift River to a divide about 3,200 feet in altitude near Summit Lake, then enters Rancheria Valley and follows it eastward to the Liard Plain.

Through the final 45 miles to Watson Lake, the corridor follows a broad drift-filled arm of Liard Valley (Lord, 1944). The altitude decreases progressively from somewhere between 2,500 and 3,000 feet near the Cassiar Mountains to about 2,250 feet at Watson Lake.

Watson Lake to Windfall, Alberta-- This part of the Fairbanks Corridor coincides with the Fort Yukon Corridor (Section 8.1.2.4).

Haines Option Corridor--From an altitude of about 1,950 feet at Haines Junction, the Haines Option Corridor to the Fairbanks Corridor ascends gradually through the broad lowlands of the Shakwak Valley, which terminate at Dezadeash Lake (Figure 8.1.2.5-3). It crosses a broad low (2,500 feet above sea level) divide at the southern end of Dezadeash Lake, then follows the broad glaciated valleys of the Takshenshini River system southward into British Columbia. The route gradually ascends to an altitude of about 3,300 feet at Chilkat Pass, crosses Three Guardsmen Pass 7 miles farther south, then descends abruptly to near sea level over the following 15 miles. It enters the broad, 2- to 3-mile-wide valley of Chilkat River near Klukwan, then follows this valley southeastward 20 miles to Haines.

The corridor is bordered on both sides by steep, rugged glaciated mountains which rise to altitudes of about 5,000 to 7,500 feet. Relief generally averages around 5,000 feet. Modern glaciers are present along both valley sides through the southern 80 miles of the corridor, and extend to altitudes as low as 2,500 feet near the coast.

Bedrock

Alaska-Yukon Border to Whitehorse--From the Alaska-Yukon border to Shakwak Valley (50 miles), the Fairbanks Corridor crosses terrain underlain by the Yukon Group, an assemblage of metamorphosed sedimentary and igneous rocks of Paleozoic and Precambrian age which has been intruded by large bodies of granodiorite and quartz monzonite (Tempelman-Kluit, 1974). A general northwest-trending structural grain is generally evident, but is masked in many places by the effects of metamorphism and by plutonic intrusions. Phyllite and argillaceous chert, interbedded with quartzite, predominate in uplands between the border and Snag Creek. Scattered exposures between Snag Creek and White River consist predominantly of massive greenstone, a resistant rock which tends to form prominent cliffs. Occasional exposures of argillaceous chert and of resistant ultramafic rocks also occur in this area. Near White River, sedimentary and volcanic rocks of the Kluane Ranges crop out southwest of Shakwak Valley and scattered granitic bodies of Mesozoic age occur immediately north of the range front.

Between White River and Haines Junction (130 miles), the Shakwak Trench separates the Yukon Plateau to the north from the Kluane Ranges to the south. The plateau here is composed of metamorphic rocks of the Yukon Group that were intruded by large and widespread granitic plutons. The Yukon Group includes extensive schists and gneisses, with more localized occurrences of recrystallized limestone in the area between White River and

Kluane Lake (Muller, 1967). Several apparent fault contacts within the Yukon Group are marked by small bodies of metamorphosed mafic and ultramafic rocks. Granitic rocks, predominantly granodiorite and quartz diorite of late Mesozoic age, form the extensive Ruby Range batholith north of Kluane Lake and more localized bodies farther to the east and west (Muller, 1967; Kindle, 1953). The rocks of the Kluane Ranges are part of a thick geosynclinal succession of volcanic and sedimentary rocks, which were severely folded along northwest-trending axes, faulted, intruded by granitic plutons, and locally metamorphosed during a period of late Mesozoic orogeny. Although an extremely varied assemblage of lithologies occurs across a 10-mile width of the range, rock types facing the Shakwak Trench along the northeast flank of the ranges are somewhat less varied. Highly sheared volcanic and sedimentary rocks of the Cache Creek Group predominate between White River and Kluane Lake. The volcanic rocks are mainly altered pyroclastic tuffs and breccias; some altered flows of andesite, basalt, and latite also are present. The sedimentary sequence consists of argillite, graywacke, and conglomerate, overlain by cherty limestone. Volcanic rocks of the Mush Lake Group consist mainly of basaltic and andesitic lavas with associated pyroclastic rocks (Muller, 1967) and underlie most of the steep slopes that overlook Kluane Lake. Between Kluane Lake and Haines Junction, sedimentary rocks of the Dezadeash Group predominate (Kindle, 1953). Lithologies include argillite, graywacke, impure limestone, tuffaceous sandstone, and bedded volcanic tuff. The Dezadeash Group is flanked by a narrower (1/2-mile-wide) belt of ultramafic rocks, mainly serpentine and peridotite, which have been sheared in places to form talc schist and serpentine schist.

East of Haines Junction, the corridor is flanked to the north and south by metamorphic rocks of the Yukon Group which have been deformed into northwest-trending folds and extensively invaded by granitic rocks of the Coast Range batholith. The Yukon Group here consists mainly of schist, gneiss, limestone, slate, and quartzite; the Coast Range intrusives consist mainly of granodiorite. Through the final 25 miles to Whitehorse, the Coast Range plutons intrude sedimentary and volcanic rocks of the Lewes River Group (Wheeler, 1961). This group is part of a Mesozoic geosynclinal assemblage comparable to that of the Kluane Ranges farther to the west. Volcanic breccia interbedded with andesite and basalt flows at the base of the succession are overlain by graywacke and conglomerate, and then by limestone.

Richards Island to Campbell Lake--The geology of this segment of the Richards Island Supply Line is discussed in Section 2.1.2.3.

Campbell Lake to Pelly Crossing--This part of the Richards Island Supply Line coincides with the Fort Yukon Corridor. Its bedrock geology is discussed in Section 8.1.2.4.

Pelly Crossing to Whitehorse--Between Pelly Crossing and Minto (20 miles), the corridor for the Richards Island Supply Line crosses a portion of the Yukon Plateau that is underlain by high-grade metamorphic rocks of probable Paleozoic age. These include gneiss, schist, quartzite, limestone, slate, and greenstone of the Yukon Group, associated with metamorphosed granitic intrusive bodies (Bostock, 1957).

The Yukon Valley south of Minto is bordered on both sides by mainly igneous rocks of predominantly Mesozoic age. These include extensive areas underlain by undifferentiated volcanic rocks and small plutons of gabbro and diorite. Farther south, near Carmacks, Tertiary volcanic rocks and a large granitic pluton also are present (Bostock, 1957).

Between Carmacks and Lake Laberge (80 miles), Mesozoic volcanic and sedimentary rocks predominate. A few small granitic plutons are present, and larger granitic bodies of the Coast Range intrusives become predominant near Whitehorse (Bostock and Lees, 1938).

A general northwest structural trend is evident in outcrop patterns of most rock units and in the general topographic grain of valleys and ranges. A comparable structural trend is shown by fold axes in the few areas where rock structures have been mapped in any detail (Wheeler, 1961).

Whitehorse to Watson Lake--Between Whitehorse and Johnsons Crossing (80 miles), the corridor crosses a complex terrain consisting of Paleozoic and Mesozoic sedimentary, metasedimentary, and volcanic rocks intruded by granitic and mafic plutons of late Mesozoic age (Wheeler, 1961; Mulligan, 1963). Igneous rocks are abundant in the immediate vicinity of the corridor along much of this segment. Near Whitehorse, granitic plutons comprise many of the uplands which flank the corridor to the west, and Cenozoic basalt flows crop out along several of the valley floors. Volcanic and metavolcanic rocks of uncertain age lie along the northeast edge of the corridor from Marsh Lake nearly to Johnsons Crossing, and scattered small mafic and ultramafic plutons crop out along both flanks of the corridor.

Late Paleozoic and early Mesozoic sedimentary and volcanic rocks of the Big Salmon Range rise above the narrow corridor segment, which follows the shore of Teslin Lake for 40 miles (Mulligan, 1963). Although Cretaceous granitic plutons form much of the heart of the range, these rocks crop out along only a short stretch of the corridor near Morley Bay.

From Morley Bay to the Cassiar Mountains (45 miles), the corridor again crosses a portion of the Yukon Plateau. late Paleozoic metamorphic rocks, including schist, gneiss, quartzite, and greenstone, predominate along this segment (Mulligan, 1963; Gabrielse, 1969).

Within the Cassiar Mountains (50 miles), bedrock consists of late Paleozoic sedimentary and metasedimentary rocks that are widely intruded by granitic plutons of Cretaceous age. Lithologies present within the late Paleozoic assemblage include chert, argillite, slate, quartzite, hornfels, limestone, and conglomerate (Gabrielse, 1969; Bostock, 1957). Small but numerous occurrences of Pleistocene volcanic rocks have been reported in the region (Lord, 1944; Gabrielse, 1969). Typically, these include lava, tuff, and agglomerate associated with flat-topped volcanic cones. Much of the volcanism was contemporaneous with late Pleistocene glaciation of the region, and at least one vent is postglacial (Gabrielse, 1969). At least five occurrences of this volcanic assemblage have been mapped along the corridor: one at Smart River, two at Swan Lake, and two along the Rancheria River.

Bedrock mapping is incomplete farther to the east. Sedimentary and metasedimentary rocks of undifferentiated Paleozoic age are known to occur widely here (Lord, 1944), and small exposures of Cenozoic volcanics were mapped by Bostock (1957).

Structural trends tend to be northwesterly throughout the region. Local deviations are common, however, especially near granitic plutons. The remarkable straightness, steepness, and continuity of the front of the Kluane Ranges, along with the highly sheared nature of its rocks, suggest that the south flank of the Shakwak Trench may be a fault scrap (Muller,

1967) or a fault-line scarp (Krinsley and others, 1971). The long, straight trough occupied by Teslin River and Teslin Lake almost certainly is also fault-controlled. Another major fault zone along the west side of Cassiar batholith was noted by Gabrielse (1969).

Watson Lake to Windfall, Alberta--This part of the Fairbanks Corridor coincides with the Fort Yukon Corridor (Section 8.1.2.4).

Haines Option Corridor--South of Haines Junction, the corridor is bordered to the west by Mesozoic igneous and sedimentary rocks of the Kluane Ranges. Conglomerate, shale, sandstone, tuff, argillite, and graywacke of the Dezadeash Group predominate for about 55 miles beyond Haines Junction, then are succeeded by volcanic rocks (andesite, basalt, rhyolite, breccia, tuff) and metasedimentary rocks (argillite, slate, crystalline limestone) of the Mush Lake Group (Kindle, 1953). Although mapping within British Columbia is incomplete, the Mush Lake Group appears to extend southward nearly to the British Columbia-Alaska border.

East of the corridor, granitic plutons and metamorphic rocks of the Boundary Ranges predominate through Yukon Territory and British Columbia. The metasedimentary rocks, chiefly schists, gneiss, slate, quartzite, and crystalline limestone, and greenstone, are most abundant to the north near Haines Junction. The granitic plutons become predominant farther south.

South of the International boundary, the corridor is flanked on both sides by metamorphic rocks of Paleozoic age. Schist, amphibolite, and phyllite predominate along the north side of Klehini Valley; slate and marble dominate the valley's south wall (MacKevett et al., 1974). Through the final 20 miles between Klukwan and Haines, the corridor crosses a massive quartz diorite pluton of Cretaceous or early Tertiary age. Less extensive igneous and metamorphic rocks (gabbro, diorite, pyroxenite, and metabasalt) form a belt 1/2-miles wide along the northeast side of the corridor.

Structural trends in the region are dominantly northwest, and are reflected by both geology and terrain. To the north, fold axes within the Kluane Ranges trend northwest, as do major troughs such as Shakwak Trench and Duke Depression which probably follow major fault lines. Farther south, foliation within metamorphic rocks near Haines shows a corresponding northwest strike, as does the major trough associated with the Chilkat River fault (MacKevett et al., 1974).

Surficial Deposits

Alaska-Yukon Border to Whitehorse--Immediately east of the Alaska-Yukon border, the Fairbanks Corridor crosses about 10 miles of unglaciated terrain, then traverses successively younger glacial deposits from Snag Creek southward to White River (Prest and others, 1968; Hughes and others, 1972; Denton, 1974). The unglaciated segment of the corridor is characterized by thick residual soils on uplands of the Yukon Plateau and by extensive deposits of loess and muck on the lower slopes and across valley floors. The succeeding 20 to 25 miles of the corridor crosses hummocky moraines and related deposits of the Mirror Creek Glaciation, relatively old glacial features which have been extensively modified by postglacial processes. Kettles and other depressions have been largely filled with silt and peat, slopes have been smoothed and lowered by mass-wasting processes, and streams such as Beaver Creek and Snag Creek have incised broad valleys through the drift. The 15 to 20 miles of the corridor immediately northwest of White River is underlain by younger and less modified deposits of the Macauley Glaciation. Macauley drift is marked by steeper and less regular topography, by numerous water-filled kettles, by a relatively thin cover of postglacial silt and peat, and by narrow and shallow incisions by postglacial streams. Young and fresh-appearing drift comparable to that of the Macauley Glaciation occurs throughout the remaining portion of the corridor between White River and Watson Lake. Although given several different local designation, these drift bodies all appear to be of Macauley age.

From White River to Kluane Lake, much of the Shakwak Trench is floored with thick deposits of till that has an irregular hummocky to drumlinlike surface in many localities. Numerous lakes and bogs occupy kettle depressions and elongate swales in the drift. The White, Donjek, and Kluane Rivers, which cross the trench in this area, occupy broad gravelly flood plains cut in older glacial outwash deposits. Smaller streams issuing from the Kluane Ranges have built thick alluvial fans across the floor of Shakwak Trench. Many of the alluvial deposits, especially those of the widely braided White and Donjek Rivers, have been reworked extensively by wind. Sand dunes and modern loess deposits are common downwind from such areas. The widespread White River Ash, formed by volcanic explosions about 1,200 and 1,900 years ago (Hughes and others, 1972), attains its greatest thickness (1/2 to 1 foot) in the area between White and Donjek Rivers. Although this unit is present through much of southwestern Yukon Territory, its usual thickness (0 to 4 inches) is insufficient to make it an important surficial deposit along other portions of the Fairbanks Corridor.

Abandoned shorelines around Kluane Lake indicate past levels 43 and 12 feet above the present lake surface. Rise of the lake to the higher strandline occurred sometime between about 500 and 300 years ago, when an advance of the Kaskawulsh Glacier blocked a former outlet to the Pacific Ocean. Subsequent downcutting along Kluane River caused the lake to recede from the 43-foot level to the 12-foot level about 250 to 300 years ago. In addition to abandoned strandlines, the south end of Kluane Lake is flanked by (1) alluvial fans, talus cones, and debris-flow deposits derived from the steep front of the Kluane Ranges, (2) the rapidly growing delta of Slims River, and (3) extensive eolian deposits, both dune sand and loess, derived from barren outwash deposits along this glacier-fed river.

East of Kluane Lake, the corridor crosses a complex of alluvial-fan gravels and till, then abruptly enters an area of subdued valley-floor relief underlain by glacial-lake sediments. The most extensive of the former lakes, Glacial Lake Champagne (Kindle, 1953), attained an altitude of about 2,800 feet and extended from the Shakwak Trench near Kluane Lake for about 100 miles through the Takhini Valley to an eastern limit near Whitehorse. The lake was dammed at the west and south by residual glacier ice in the Shakwak Trench and at the east by glacier remnants in the Whitehorse area. A series of beaches and wave-cut escarpments extend down to an altitude of about 2,300 feet, reflecting gradual downcutting of the lake outlet (Kindle, 1953; Hughes and others, 1972). Surficial deposits associated with the lake include: (1) widespread stratified silt and clay along the floor of Takhini Valley, (2) beach deposits of sand and gravel between 2,300 and 2,800 feet in altitude near the bases of valley walls, (3) abandoned deltas and fan deposits of sand and gravel where incoming streams intersected former lake margins, and (4) dune fields composed of sand winnowed by wind from the beaches and transported northward across the valley. Glaciolacustrine silt and clay in central parts of the valley are more than 200 feet thick in places (Kindle, 1953).

A smaller and much younger lake was formed by successive advances of the Lowell Glacier across Alsek Valley in about A.D. 1725 and 1850 (Kindle, 1953; Post and Mayo, 1971). The glacier dam impounded Alsek River to form an elongate lake which extended northward 25 miles up Alsek Valley and 27 miles farther into Shakwak Trench. Shorelines about 2,240 feet in altitude outline two arms of the lake which cross the trench north and northeast of Haines Junction.

Richards Island to Campbell Lake--The geology of this segment of the Richards Island Supply Line is discussed in Section 2.1.2.3.

Campbell Lake to Pelly Crossing--This part of the alternative supply line from Richards Island coincides with the Fort Yukon Corridor. Its surficial deposits are discussed in Section 8.1.2.4.

Pelly Crossing to Whitehorse--Between Pelly Crossing and Minto, and also across the divide west of Lake Laberge, the corridor follows narrow glacial troughs cut into uplands of the Yukon Plateau. Valley floors are cut into bedrock, but usually bear thick covers of glacial till and meltwater deposits. Kame terraces and other sand and gravel deposits may be fairly abundant along valley walls, and extensive deposits of late-glacial to postglacial alluvium probably cover most valley floors. The trough which connects Pelly Crossing with Minto occupies relatively old glaciated terrain. Loess and colluvium may form thick deposits here, especially along slope bases.

The major valley segments along the corridor probably are underlain by thick deposits of coarse alluvium. The Yukon Valley floor southeast of Minto may contain thick deposits of outwash derived from a moraine front which lies about midway between Minto and Carmacks. South of the moraine, glaciolacustrine sediments could occur in localities where water bodies were dammed behind barriers of ice or drift. Unstable bodies of clayey till may also be present on lower hillsides.

Postglacial stream incision has created alluvial terraces along many of the major drainage systems. Terrace faces expose mainly alluvium and drift, with bedrock locally exposed beneath the unconsolidated deposits.

Landslide deposits may be present along valley walls, especially where undercut and oversteepened by glacial erosion. Solifluction aprons may be extensive in places, especially beyond the late Wisconsin ice limits.

Whitehorse to Watson Lake--The broad valley floors followed by the corridor immediately southeast of Whitehorse probably are underlain by thick deposits of glacial drift. Water-washed sand and gravel deposits are present in esker complexes near Whitehorse (Wheeler, 1961), but clayey, silty till probably is prevalent elsewhere in pitted terrain along the valley floor. Abandoned shorelines around Marsh Lake were mapped by Wheeler (1961). These suggest that clayey, silty glaciolacustrine deposits may be fairly abundant along this part of the valley.

The narrower valley between Marsh Lake and Teslin Lake probably is underlain by a complex of till and alluvium, with kame terraces and lateral moraines along portions of the flanking valley walls. Bedrock may occur close to the surface in places, especially where streams have cut deeply into the glacial deposits. The numerous lakes along the divide between the west- and east-flowing drainages probably are moraine dammed, although some may occupy ice-scoured bedrock basins.

High-level shorelines surrounding Teslin Lake are mentioned by Mulligan (1963). The lake apparently stood 300 feet or more above its present level during deglaciation, when the Teslin River was blocked by glacial-meltwater deposits. Much of the corridor along the northeast shore of the lake may cross clayey to sandy lacustrine deposits. Comparable deposits may continue for 10 to 15 miles beyond Morley Bay, where the corridor follows a probable former arm of the lake southeastward into the Yukon Plateau.

Within the uplands of the Yukon Plateau and the Cassiar Mountains, the corridor continues to follow a series of glaciated valleys. Till and outwash probably predominate along most valley floors, and low divides may be underlain by moraines rather than by near-surface bedrock. Existing lakes in this area probably are bordered by water-washed sand and gravel deposits, but clayey or silty lacustrine sediments may be associated with former lake shores in some localities.

East of the Cassiar Mountains, the corridor follows a broad drift-filled arm of the Liard Plain (Lord, 1944). Glacial deposits exceed 200 feet in thickness in many places (Bostock, 1948). The many small lakes along this portion of the corridor suggest that the surface may be a widespread hummocky till plain. The drift is covered in places by glaciofluvial sand and gravel, and by postglacial fluvial sediments.

Watson Lake to Windfall, Alberta--This part of the Fairbanks Corridor coincides with the Fort Yukon Corridor (Section 8.1.2.4).

Haines Option Corridor--Between Haines Junction and the south shore of Dezadeash Lake, the corridor lies within part of the broad basin once occupied by Glacial Lake Champagne (Kindle, 1953). It follows beach deposits through portions of this area, but elsewhere it crosses clayey to silty glaciolacustrine beds. Alluvium also appears to be widespread on the valley floor, according to mapping by Kindle (1953). Along the west shore of Dezadeash Lake, a series of drift tongues formed by small alpine glaciers extends across the corridor from valleys of the Kluane Range. Relatively unstable bouldery moraines might occur in the drift.

Between Dezadeash Lake and Chilkat Pass, the corridor follows a series of deep, steep-sided glacial valleys. Although detailed surficial geologic mapping is not available, the relatively wide (2 to 4 miles) and gently ascending floors of the valleys suggest deep filling by glacial and postglacial sediments. Till may be present throughout the valley system, but probably is largely buried beneath sheets of outwash, deltaic sediments near the south end of Glacial Lake Champagne, and postglacial alluvium. Talus cones, solifluction aprons, and other colluvial deposits probably are present along bases of flanking mountain walls, but these are unlikely to be widespread across the broad valley floors.

Bedrock is widely exposed across Chilkat Pass, Three Guardsmen Pass, and the steep valley segment between this area and the British Columbia-Alaska border. Thick deposits of glacial drift are probably rare and modern surficial sediments are probably limited to thin stringers of alluvium along stream channels, alluvial fans at mouths of tributary streams, and colluvial aprons along valley sides. Landslide and avalanche deposits, if present, may extend all the way across the relatively narrow valley floors.

In Alaska, the corridor follows the broad, alluvium-filled floors of the Klehini and Chilkat Rivers. It lies upon the modern flood plains of these rivers for only short distances, and usually occupies alluvial fans and colluvial deposits along the bases of flanking mountain slopes.

Elevated marine deposits, which include soft, plastic clays, are present to altitudes of at least 300 feet in the Haines area (Lemke and Yehle, 1972).

Mineral Resources

Metallic and Nonmetallic Mineral Resources--The only segments of the Fairbanks Corridor that do not coincide with either the Fort Yukon Corridor or the proposed route are between the Yukon-Alaska boundary and Watson Lake, Yukon Territory, the Haines Option, and part of the corridor that would be followed by the supply line from Richards Island if the Fairbanks Corridor were selected for a pipeline.

The only major metallic or nonmetallic mineral deposits in or near these parts of the corridor are near the Old Pueblo and Big Chief-Little Chief properties in the Whitehorse Copper Belt. Total production (1897-1930) from this area was 13 million pounds of copper (with minor amounts of silver and gold) from 300,000 tons of ore. Production plus reserves for the Whitehorse Copper Belt total between 1 and 15 million tons of ore (Douglas, 1970, map 1252 A; Little and others, 1970, table IX-2).

The old Rainy Hollow mining district of British Columbia is near the Haines Option of the Fairbanks Corridor. Although possibly valuable for base metals and silver (Eakin, 1919, p. 26), prospects in this district were not developed into major mines.

Data are not available on specific deposits of sand, gravel, and rock suitable for use as a construction material. Adequate quantities of all are probably available in most parts of the corridor. Quite possibly materials sites along the Alaska Highway and other roads could be enlarged if a pipeline were constructed in this corridor.

Oil and Gas--A 300-mile-wide zone along the Fairbanks Corridor would encompass the Whitehorse sedimentary basin as well as the basins and sedimentary provinces along the Fort Yukon Corridor (Section 8.1.2.4). Though the rocks in the Whitehorse basin may be prospective for gas, McCrossan and Porter (1973, p. 683) considered the probability of recoverable accumulations too low for an estimate of potential.

Seismicity

The earthquake history along the Fairbanks Corridor is short relative to the time over which strains accumulate to produce an earthquake, hence the historic record of seismicity is a limited guide to future seismic risk. Earthquakes of magnitude 6 and larger are potentially destructive, and earthquakes of magnitude 5 may even cause local damage. North of 60° N latitude, the seismic history of Canada is probably complete since the early 1930's for earthquakes as small as magnitude 6 and since the late 1950's or early 1960's for shocks as small as magnitude 5 (Stevens and Milne, 1973; Leblanc and Wetmiller, 1974). The historic record is somewhat better for eastern British Columbia and Alberta.

The historic record indicates that the level of earthquake activity along the Fairbanks Corridor varies from low to high. From the Alaska-Yukon border to Haines Junction, the corridor parallels or follows the Shakwak fault, an active member of the Denali fault system. In this segment epicenters of earthquakes as large as magnitude 6.5 and of several shocks in the magnitude 5 class have been located within 50 miles of the corridor. Farther east, in the vicinity of Whitehorse, epicenters as large as magnitude 5.3 have been located within 25 miles of the corridor. Earthquakes as large as magnitude 5.0 are known to have occurred in the vicinity of Watson Lake where the Fairbanks Corridor joins the Fort Yukon Corridor. The historic level of seismicity along the Richards Island Supply Line corridor between the main Fort Yukon and Fairbanks Corridors is low.

The earthquake potential along the Fairbanks Corridor from the Alaska-Yukon border to the junction with the Fort Yukon Corridor may be specified in terms of maximum expected eearthquakes as summarized in Table 8.1.2.9-13. The potential along the Richards Island Supply Line corridor south from the junction with the Fort Yukon Corridor may be specified in terms of a maximum expected earthquake of magnitude 5.5. The maximum expected earthquake is the largest earthquake that on the basis of existing knowledge may reasonably be expected to occur along a specified segment; it everywhere equals or exceeds the largest known historic earthquake. The zonation of the corridor might be further refined if more complete geologic and geophysical data were available.

At present, no faults with surface expression are known to be active; however, detailed geologic field investigations in regions of high seismicity might reveal evidence for geologically recent movements (Stevens and Milne, 1973). Without knowledge of the seismically active faults along and adjacent to the corridor, there is no basis for assigning the maximum expected earthquakes to a specific fault and the occurrence of the maximum expected earthquake anywhere along the corridor may be considered possible.

Mass Wasting

Alaska-Yukon Border to Whitehorse--The 50-mile segment of the corridor between the Alaska-Yukon border and White River traverses gentle to moderate slopes of the Yukon Plateau and the Wellesley Basin. Except for occasional knobs and ridges of resistant bedrock, no slopes rise to any appreciable heights above the corridor. Mass wasting here probably is limited to: (1) solifluction along some valley floors where poor drainage and near-surface permafrost have inhibited forest growth, (2) frost creep on wind-swept crests of morainal and bedrock ridges, and (3) occasional minor falls or slides of material down locally steep slopes which flank Macauley Ridge and Horsecamp Hill.

Throughout the length of Shakwak Trench, the corridor is subject to large and sudden falls, slides, and flows of rock and debris down the steep northward-facing flank of the Kluane Ranges. Slopes here have been oversteepened in many places by glacial erosion, and possibly also by fault displacement during late Pleistocene and Holocene time. Much bedrock consists of relatively incompetent sedimentary and pyroclastic rocks, many of the exposed rock faces have been intensely shattered by faulting, and bedding planes in some areas dip steeply toward the trench. Sediments exposed in terraces along the White River include several mudflow deposits; numerous debris flows have occurred near the south end of Kluane Lake (Hughes and others, 1972). Talus cones, formed by rock falls and associated mass movements, occur widely along the south flank of Shakwak Trench. The northeast flank of the trench, in contrast, consists of relatively low gentle slopes that flank the Yukon Plateau. Although solifluction and creep probably are common at higher altitudes, little detritus moves into the Shakwak Trench by mass wasting.

East of Haines Junction, both flanks of the Takhini Valley are relatively low and gentle. Large and sudden mass movements are unlikely here, although some of the steeper alluvial fans may be subject to mudflows and slushflows. The greatest potential mass-wasting hazards through this sector probably are slides and flows in the lacustrine silts and clays that mantle the valley floor. These may be particularly significant where stream incisions into lacustrine beds have created locally steep slopes.

Richards Island to Campbell Lake--The geology of this segment of the Richards Island Supply Line is discussed in Section 2.1.2.3.

Campbell Lake to Pelly Crossing--This part of the alternative supply line from Richards Island coincides with the Fort Yukon Corridor. Its mass wasting problems are described in Section 8.1.2.4.

Pelly Crossing to Whitehorse--Although altitudes seldom exceed 6,000 feet in the Pelly Crossing-Whitehorse area, many slopes have been oversteepened by glacial erosion or postglacial stream incision. Areas of greatest potential mass-wastage hazard include:

1. Pelly Crossing-Minto segment, where thick metastable solifluction deposits may be present;

2. Yukon Valley between Minto and Carmacks, where the river is undercutting its east valley side in at least 2 localities; and

3. The divide area west of Lake Laberge, especially where the corridor is compressed between Fox Lake and steep valley walls.

Whitehorse to Watson Lake--Landslides and related slope movements probably are common in many of the glacially oversteepened valleys followed by the corridor southeast of Whitehorse. The extreme narrowness of some of these valleys makes it difficult to avoid placing structures in hazardous positions near the bases of steep, high slopes. Lacustrine sediments, which probably are widespread around Teslin Lake and elsewhere along this part of the corridor, are subject to rotational slides and to both slow and rapid flowage. Particularly hazardous zones occur where these sediments have been entrenched by postglacial streams, forming steep scarps. Alluvial terraces occur along the Yukon River near Whitehorse and along the Morley, Swift, and Rancheria Rivers farther east. Steep terrace faces are subject to slumps and debris slides, especially where undercut at the base by lateral stream erosion.

Watson Lake to Windfall, Alberta--This part of the Fairbanks Corridor coincides with the Fort Yukon Corridor (Section 8.1.2.4).

Haines Option Corridor--Potential mass-movement problems are relatively minor north of Chilkat Pass. To the south, however, they could constitute severe hazards to a pipeline.

Clayey lacustrine sediments may be abundant along the initial 35 to 40 miles south of Haines Junction. These sediments may be particularly unstable where exposed on terrace faces and river bluffs created by postglacial stream incisions. Locally steep slopes, which may be underlain by lacustrine sediments, also occur along the southwest side of Dezadeash Lake. The lake extends to the base of the west valley wall, forcing the corridor to cross a relatively steep apron at the foot of the Kluane Ranges. Geologic hazards on this segment of the route could be: (1) slides and avalanches from slopes above, (2) slides or flows of underlying unstable sediments, and (3) undercutting by wave erosion along the shore of Dezadeash Lake.

Between Dezadeash Lake and Chilkat Pass, the corridor tends to follow the midlines of fairly broad glacial valleys. Although avalanches, slides, and rock and debris falls probably originate from the steep valley sides, they would seldom reach the center of the valley and endanger structures located there.

South of Chilkat Pass, mass-wasting hazards would be intensified by (1) heavy snowfall on the windward side of the Coast Mountains, (2) precipitous mountain slopes in direct contact with the corridor, and (3) widespread marine clays near Haines. Heavy snowfall and high, steep slopes probably favor avalanche activity throughout this area, and barren avalanche tracks are conspicuous. The corridor traverses steep slopes south of Three Guardsmen Pass, and lies directly at the base of glacially oversteepened valley walls throughout the Alaskan portion of the corridor. These slopes probably are subject to a wide range of sudden mass movements--falls, slides and avalanches--which would endanger the corridor. Closer to Haines, the corridor crosses alluvial and colluvial sediments locally resting on sensitive marine clays (Lemke and Yehle, 1972). These deposits are subject to translatory or rotational slides at times of earthquakes or other disturbances.

Erosion

Alaska-Yukon Border to Whitehorse--Widespread erosion is probably active only along the Fairbanks Corridor segment between the Alaska-Yukon border and White River. Slopes crossed by the corridor here, although gentle, are commonly several miles in length. Ice-rich permafrost provides a potential source of runoff water, and is subject to thermal erosion on slopes and along streambanks. The broad valley floors of Snag Creek and Beaver Creek appear to be underlain by thick silt deposits, which are readily mobilized by erosion processes.

The floor of Shakwak Trench, in contrast, is seldom subject to erosion problems. Although sloping colluvial aprons are present along both flanks of the trench, the center is usually comparatively flat. Hummocky drift deposits have locally steep slopes, but these are seldom more than a few hundred feet in length. Most of the streams that cross the trench have beds of coarse gravel that are subject to reworking by the highly braided streams themselves, but tend to be stable under most other erosion processes. Some erosion by waves and currents is taking place along the shores of Kluane Lake, but this appears to be minor and is very local. In general, Shakwak Trench is the site of net deposition rather than erosion. Extensive fans are forming in many areas, fan and deltaic deposits are filling parts of Kluane Lake, dune sand and loess are accumulating in some localities, and colluvial cones and aprons are accreting along the flank of the Kluane Range.

Although most of Takhini Valley also is subject to net deposition, corridor segments along Dezadeash River (25 miles) and Takhini Valley (20 miles) are probably subject to erosion. Downcutting may be fairly active along Dezadeash River, which flows into Alsek River and thence to the Pacific Ocean. The Dezadeash drainage thus has a much lower base level than all other streams of the region all of which flow into the Yukon River system. Downcutting by the Dezadeash River has steepened the gradients and increased the erosion potential of its tributaries. Downcutting also has created many locally steep slopes that are subject to erosion by other processes. In contrast to the generally coarse-grained deposits of the

Shakwak Trench, Takhini Valley is floored with lacustrine silts and clays. These are readily eroded by bank cutting along streams and are subject to gullying on slopes.

Richards Island to Campbell Lake--The geology of this segment of the Richards Island Supply Line is discussed in Section 2.1.2.3.

Campbell Lake to Pelly Crossing--This part of the alternative supply line from Richards Island coincides with the Fort Yukon Corridor. Its erosion problems are discussed in Section 8.1.2.4.

Pelly Crossing to Whitehorse--Erosion problems along this segment of the supply line corridor consist mainly of bank cutting by meandering streams such as the Yukon and Nordenskiold Rivers, downcutting along some stream courses, and gullying of alluvial terrace faces. The generally low gradients of streams along the corridor and the abundance of coarse alluvium tend to inhibit surface runoff and associated erosion processes in most areas.

Lateral erosion by the Yukon River appears to be most serious about 25 and 3 miles north of Carmacks where, as discussed in previous sections, the river impinges against its eastern valley side. A comparable problem area along the Nordenskiold River is 2 miles south of Carmacks.

Extensive high terraces border most major streams of the region (Bostock and Lees, 1938). It is unclear whether or not downcutting is still taking place. Stability of the terrace faces has not been assessed in any detail.

Whitehorse to Watson Lake--The generally coarse-grained drift and alluvium of mountain valleys traversed by the corridor between Whitehorse and Watson Lake probably would not be eroded greatly under most conditions. Erosion is taking place chiefly where lowering of postglacial base levels has resulted in stream downcutting. The most severe erosion here probably is taking place where: (1) silty to clayey lacustrine sediments occupy moderate to steep slopes; (2) active stream entrenchment into unconsolidated sediments has created steep and unstable terrace faces; and (3) streams are eroding laterally into high banks composed of unconsolidated deposits. These zones cannot be delineated more precisely on the basis of the geologic information presently available for this part of the corridor.

Watson Lake to Windfall, Alberta--This part of the Fairbanks Corridor coincides with the Fort Yukon Corridor (Section 8.1.2.4).

Haines Option Corridor--Erosion problems are extremely localized north of Chilkat Pass. Steep terrace scarps on lacustrine clays and silts of Glacial Lake Champagne may be subject to gullying in places, and the corridor could be affected by wave erosion where it is compressed into a very narrow zone at the southwest end of Dezadeash Lake. Some downcutting may still be taking place along the major river systems but could affect the corridor only indirectly--by increasing the height and steepness of terrace scarps.

South of Three Guardsmen Pass, erosion problems are greatly intensified partly because heavy precipitation on the windward flank of the Coast

Mountains causes relatively high runoff rates. Rapid erosion along the corridor could occur where it (1) descends rapidly down a steep valley tributary to Klehini River, (2) crosses strongly scouring streams at the bases of steep valley walls, and (3) runs along the banks of glacier-fed rivers with high fluctuations in discharge.

Marine erosion processes, especially those associated with tsunamis, are an additional problem near Haines.

Permafrost

Alaska-Yukon Border to Whitehorse--Although the entire length of the Fairbanks Corridor northwest of Watson Lake lies within the zone of discontinuous permafrost, only the 115 miles from the Alaska-Yukon border to Kluane Lake crosses widespread permafrost (Brown, 1967). From Kluane Lake eastward to Watson Lake, the corridor traverses the southern fringe of the permafrost zone where perennially frozen ground is restricted to particularly favorable sites such as peat bogs.

Active thermokarst features, indicative of ice-rich permafrost, are most abundant near the northwest end of the corridor. The extensive permafrost here is associated with the thick, poorly drained loess, muck, and residual soils of unglaciated terrain. Thaw lakes are particularly abundant along valley floors through this area, and local thermokarst topography is present farther to the southeast across drift surfaces. Although thaw lakes are more infrequent there, disturbance of insulating plant cover along the Alaska Highway has created polygonal networks of troughs above thawing ice-wedge systems (Hughes and others, 1972).

Active thaw lakes a few miles northwest of White River are reported by Hughes and others (1972), and many probable thaw lakes are evident along the corridor from 4 to 12 miles southeast of the river. Thaw lakes and other obvious permafrost features are less abundant to the southeast along the floor of Shakwak Trench. Permafrost is present, however, in many of the older poorly drained surficial deposits, and was encountered at several places during Alaska Highway relocation work. The presence of permafrost is often marked here by areas of black spruce muskeg (Krinsley and others, 1971).

Although Kindle (1953) found no permafrost east of Kluane Lake, studies by Wheeler (1961) and relocation work along the Alaska Highway have delineated at least two occurrences of permafrost along the floor of Takhini Valley 25 and 45 miles west of Whitehorse. Recent thermokarst depressions in this area also are reported by Rampton (1972).

Richards Island to Campbell Lake--The geology of this segment of the Richards Island Supply Line is discussed in Section 2.1.2.3.

Campbell Lake to Pelly Crossing--This part of the alternative supply line from Richards Island coincides with the Fort Yukon corridor. Permafrost distribution and character are discussed in Section 8.1.2.2.

Pelly Crossing to Whitehorse--The entire region between Pelly Crossing and Whitehorse lies within the southern fringe of the discontinuous permafrost zone (Brown, 1967). Permafrost is present at higher altitudes, and occupies favorable portions of valley bottoms such as north-facing slope bases, fine-grained deposits beneath moss cover, and thicker organic terrain.

Permafrost may be thickest, most extensive, and richest in ice content within the old drift and postglacial deposits between Pelly Crossing and Minto. Farther to the south, permafrost should be more restricted within the relatively young coarse alluvium of the Yukon River flood plain. Permafrost problems might be intensified across the divide west of Lake Laberge where perennially frozen ground would tend to be favored by slightly higher altitudes, shading by adjacent mountain slopes, and abundant till, solifluction debris, and other fine-grained deposits.

Whitehorse to Watson Lake--Permafrost becomes increasingly rare southeastward from Whitehorse. Based on construction records of the Alaska Highway, about 10 percent of the corridor from Whitehorse to Teslin Lake and along the northeast shore of the lake is underlain by permafrost (Krinsley and others, 1971). East from Teslin Lake and through the Cassiar Mountains, about 6 to 8 percent of the corridor contains permafrost. In the Liard Plain, only one-half mile of permafrost was encountered over a distance of 146 miles. In general, permafrost along this part of the corridor is restricted to higher altitudes, to north- and northeast-facing slopes, and to organic terrain. It usually is limited to fine-grained soils, especially those with good insulating peat cover. Despite its isolated occurrences, permafrost may extend completely across narrow sectors of the corridor such as lake shores and alpine valleys.

Watson Lake to Windfall, Alberta--This part of the Fairbanks Corridor coincides with the Fort Yukon Corridor (Section 8.1.2.4).

Haines Option--Permafrost generally is absent south of Haines Junction. Although some small bodies of permafrost are probably present at higher altitudes along the corridor, the generally coarse-grained and well drained geologic materials and soils in the mountain valleys should not be subject to serious thaw problems.

Soils

The Campbell Lake-Pelly Crossing and Watson Lake-Windfall sections of the Fairbanks Corridor have been described in a previous section (8.1.2.4) and will not be repeated here.

From Pelly Crossing to Whitehorse and from the Alaska-Yukon border to Whitehorse the proposed corridor would traverse Cambisols almost exclusively. This area is in the Boreal Forest vegetation region.

The Whitehorse to Watson Lake segment shares the same soil and vegetation types with the exception of the Cassiar Mountains-Rancheria River Valley region. Here, coarse textured Lithosols and associated Regosols and Cambisols have developed on the hilly to mountainous terrain.

Water Resources

Surface Water

The Fairbanks Corridor north of Windfall, including the Richards Island Supply Line, crosses about 712 minor streams and 55 major streams (Table

8.1.2.9-12). A summary of streamflow data collected by the Water Survey of Canada is presented in Table 8.1.2.5-1.

Tributaries to the Yukon and Alsek Rivers draining the St. Elias Mountains and the Boundary Ranges are mostly fed by glaciers. The maximum flows usually occur in late July or early August as a result of a combination of high precipitation and glacier melt. Streams draining the Pelly Mountains and the Yukon-Liard divide usually have peak flows caused by rain and snowmelt in May or June. Minimum flow usually occurs in March.

The Fairbanks Corridor crosses many glacier-fed rivers with important or dominant amounts of glacier runoff. The White River is subject to severe flooding by breakout of ice-dammed lakes. The Alsek River below Haines Junction has been dammed in the recent past by Lowell Glacier, which is subject to periodic surges (Post, 1969). Within the last 300 years, a glacier-dammed lake has extended 45 miles up the Alsek valley from Lowell Glacier and covered two valleys now crossed by the Alaska Highway (Post and Mayo, 1971).

Streams originating in the Cordilleran Region contain medium-hard water of the bicarbonate type. During the winter months when streams are frozen and the terrain is snow covered, suspended-sediment concentrations are low, generally less than 70 mg/l (Stichling, 1974). Suspended-sediment concentrations during the open-water season are quite variable. Highest concentrations occur during spring breakup and summer-storm events.

The Haines Option Corridor from Haines Junction, Yukon Territory, to Haines, Alaska, would closely follow an existing highway and would cross watersheds of the Dezadeash, Tatshenshini, Klehini, and Chilkat Rivers. It would also cross about 54 lesser streams (see Table 8.1.2.9-14).

Streamflow data have been collected on the Dezadeash River and the Chilkat River, but there are no data available on the smaller watersheds. Maximum flow on the Dezadeash River usually occurs during snowmelt in May or June. The maximum known discharge at the gaging station at Haines Junction was 10,100 cfs on July 16, 1953 (McAully, 1973, p. 4). Streamflow in the Chilkat River is significantly affected by glacial melt and maximum flow can occur at any time in the summer. The maximum known discharge at the gaging station 16 miles north of Klukwan was 22,000 cfs on September 15, 1967 (U.S. Geol. Survey, 1967, p. 29). Minimum flow usually occurs in March or April.

There is little water-quality information from the basins between Haines Junction and Haines. Thomas (1964) reported that the total hardness of streamflow ranged from 0 to 60 mg/l (as CaCO) and the mineral content ranged from 0 to 50 mg/l. At the gaging station on the Chilkat River the suspended-sediment concentration was 1,180 mg/l on October 10, 1967 (U.S. Geol. Survey, 1968, p. 44).

Ground Water

The Fairbanks Corridor is mostly underlain by glacial and nonglacial surficial deposits ranging from very fine lake deposits to very coarse outwash and alluvial deposits. Discontinuous permafrost underlies the corridor south to Watson Lake, Yukon Territory, as well as the Haines Option. From the Alaska-Yukon border to Kluane Lake, Yukon Territory, permafrost is widespread. Southeast of Whitehorse discontinuous permafrost occurs only in the higher altitudes, on north-facing slopes, and in muskeg areas (CAGPL, 1974c). Ground water in the discontinuous permafrost zone has been obtained from unfrozen alluvium adjacent to rivers (Brandon, 1965).

Table 8.1.2.5-1 Summary of selected streamflow records along the Fairbanks Corridor, including the Richards Island Supply Line and the Haines Option Corridor

Station no.	Name	Drainage area (sq.mi.)	Location	Discharge records	Type of gage	Operation	Mean (cfs) (in)	Max. daily (cfs)	Min. daily (cfs)	Remarks
	ALSEK RIVER:									
08AA001	Aishihik R nr Whitehorse, Y.T.	1,620	60°51'40" 137°03'40"	50-68 69-	M R	C C	508 4.26	5,050 6-20-67	79.0 3-20-52	
08AA003	Dezadeash R at Haines Jct., Y.T.	3,200	60°44'54" 137°30'19"	52-70 71-	M R	C C	1,530 6.49	10,100 6-28-61	238 3-22-67	
	YUKON RIVER:									
09AB008	M'Clintock R nr Whitehorse, Y.T.	597	60°36'45" 134°27'27"	55-	R	C	361 8.21	b3,680 6-1-72	63.6 3-8-72	
09AB001	Yukon R at Whitehorse, Y.T.	7,500	60°42'50"	02-27 28-42 43-69 70-	M M M R	S C C C	8,430 15.3	b22,800 8-9-53	1,150 5-19-62	Regulated since 1969.
09AC004	Takhini R at O of Kusawa L, Y.T.	1,570	60°36'37" 136°07'26"	52,55-56, 58,63 53-54,59-62, 64- 57	R R M	S C C	1,780 15.4	b9,880 6-21-64	173 4-23-72	
09AC001	Takhini R nr Whitehorse, Y.T.	2,040	60°51'08" 135°44'21"	48-64 65-	M R	C C	2,150 11.1	17,200 9-2-49	153 2-19-51	Regulated since 1948.
09AE003	Swift R nr Swift River, B.C.	1,280	59°55'50" 131°46'04"	56-57,59-60 61-	M R	S C	1,740 18.5	b15,500 6-11-64	205 3-26-69	
09AE004	Gladys R at O of Gladys L, B.C.	737	59°54'20" 132°54'50"	56-60 61-	R R	S C	528 7.73	b4,250 6-13-64	90.7 4-10-72	

continued on next page

1/ Water Survey of Canada annual data reports.

Table 8.1.2.5-1 Continued

Station no.	Name	Drainage area (sq.mi.)	Location	Discharge records	Type of gage	Oper- ation	Mean (cfs) (in)	Max. daily (cfs)	Min. daily (cfs)	Remarks
09AE001	Teslin R nr Teslin, Y.T.	11,700	60°29'07" 133°18'04"	44-46 48-	M M	S C	10,800 12.5	65,000 6-28-62	1,350 2-24-56	
09AH001	Yukon R at Carmacks, Y.T.	33,600	62°05'45" 136°16'18"	51-59 60-	M R	C C	25,800 10.4	b102,000 6-23-64	4,800 3-15-52	Richards I. Supply Line
09BC001	Pelly R at Pelly Crossing, Y.T.	19,700	62°49'47" 136°34'50"	51-60 61-	M R	C C	13,900 9.58	146,000 6-11-64	1,020 4-17-56	Richards I. Supply Line
09CA002	Kluane R at O of Kluane L, Y.T.	1,910	61°25'37" 139°02'56"	52-62 63-	M R	C C	2,470 17.6	b13,600 8-15-71	19.0 2-27-71	
09EA003	Klondike R ab Bonanza Creek, Y.T.	3,010	64°02'34" 139°24'28"	65-	M	C	2,200 9.93	22,600 5-29-72	180 4-2-70	Richards I. Supply Line
09EB001	Yukon R at Dawson, Y.T.	106,000	64°04'20" 139°25'21"	45-52, 56- 54-55	M M	C S	78,000 9.99	526,000 6-11-64	6,350 2-22-51	Richards I. Supply Line

continued on next page

Table 8.1.2.5-1 Continued

M Manual gage.
R Recording gage.
C Continuous operation.
S Seasonal operation.

a Estimated.
b Maximum instantaneous discharge.
c Insufficient data.
d Maximum monthly mean discharge.

e Minimum monthly mean discharge
f From "Hydraulic and Geomorphic Characteristics of Rivers in Alberta."

NOTE: The number of years used to compute or estimate the mean discharge does not necessarily correspond to the full period of continuous gage operation shown. Means for seasonal records were estimated in a few cases. These estimates should be reasonably reliable, since winter flows were generally low.

The maximum daily discharges are shown for most stations because that was all that was published. Instantaneous discharges are shown when they are available. The maximum daily discharge may be considerably smaller than the instantaneous peak for small and intermediate streams. Maximum stages are not shown, but they may or may not have occurred at the time of maximum discharge. The highest stage might occur as the result of an ice jam.

Caution should be used in interpreting minimum-flow figures. They are the lowest values published, but lower values may have occurred during periods of seasonal observations.

Calcium or magnesium bicarbonate waters occur along the corridor. At the Takhini Hot Springs near Whitehorse, the water is a calcium sulfate type with a concentration of 2,658 mg/l dissolved solids (van Everdingen, 1974). Shallow ground-water aquifers in the surficial deposits are susceptible to pollution from surface seepage.

No ground-water data were available for the Haines Option Corridor.

Vegetation

The major plant communities of this corridor (Figures 8.1.2.1-2 and 8.1.2.4-6) are identical to those of the Fort Yukon Corridor (Section 8.1.2.4). Only those segments of the Fairbanks Corridor not in common with the Fort Yukon Corridor (Figures 8.1.2.5-1 and 2) are discussed.

Pelly Crossing to Whitehorse

This segment of the corridor lies within the Central Yukon Section of the Boreal Forest (Rowe, 1972). White spruce has its best development on protected lowlands where it attains saw-lumber size. White spruce intermixed with willow and trembling aspen occurs as islands of forest among areas of grassland on mountain slopes. On uplands white spruce is associated with alpine fir which at higher elevations extends beyond the range of spruce to treeline at 4,000 to 5,000 feet above sea level. Black spruce occupies wet organic soils and is often accompanied by white spruce. Lodgepole pine is dominant on sandy soils in the southeastern part of the section.

Alaska-Yukon Border to Watson Lake

Between the Alaska-Yukon border and a point west of Haines Junction, the Fairbanks Corridor (Figure 8.1.2.5-1) is within the Kluane Section of the Boreal Forest (Rowe, 1972). The climate is cold and dry in the rainshadow of the St. Elias Mountains and the forest potential is poor. River-valley forests of white spruce, aspen and balsam poplar are the best developed but even here they are rarely closed and the vegetation appears as parkland interspersed with grassland communities. In benchlands along the valleys, the associates of white spruce are trembling aspen and Alaska paper birch. Open forest of white spruce with a low shrub understory of willows and birches grades into low shrub tundra of dwarf birch, heaths and willows (Salix glauca) and, at higher elevations, into grass-sedge meadows on slopes, and cottongrass-tussock communities in areas of poor drainage. White and black spruce both occur on peatlands but the latter is infrequent in the area, as is tamarack. Lodgepole pine is lacking in this section.

From slightly west of Haines Junction the corridor enters the Central Yukon Section of the Boreal Forest, which extends beyond the Teslin River, crosses the Eastern Yukon Section and, west of Watson Lake, enters the Upper Liard Section (Rowe, 1972). The vegetation of these sections is treated in the Alaska-Yukon border to Pelly Crossing and Pelly Crossing to Watson Lake segments of the Fort Yukon Corridor (Section 8.1.2.4).

Haines Option Corridor

This corridor (Figures 8.1.2.5-1 and 3) begins in the Central Yukon Section of the Boreal Forest and lies within it for about 20 miles before crossing the Kluane Section which extends into British Columbia.

In British Columbia much of the rugged, mountainous terrain crossed is occupied by snow fields, glaciers, and alpine tundra. Well-developed but rarely closed forests of white spruce, aspen and birch occur in the river valleys.

Approaching the panhandle of Alaska, areas to the west of the corridor in British Columbia have valley forests of the Pacific Coastal Forest Formation. White spruce occurs mixed with Sitka spruce (Picea sitchensis) and in patches where Coast Forest is best developed Sitka spruce or Sitka spruce-western hemlock (Tsuga heterophylla) occupy alluvial soils. Western hemlock is mixed with amabilis fir (Abies amabilis) on well-drained sites and with western red cedar (Thuja plicata) on wetter soils. The 45 mile segment in Alaska crosses alpine tundra and coastal forest communities.

Wildlife

The wildlife data contained in this section were drawn entirely from the Applicant's documents (CAGPL, 1974e).

Fish

Most of the drainage along the western part of Fairbanks Corridor is in the Yukon River system and has an aquatic fauna similar to that described for the Porcupine River (Section 8.1.2.4). However, most of the corridor for the Richards Island Supply Line and that portion of the corridor east of the town of Swift River are in the Mackenzie River drainage. The general fish fauna of the Mackenzie is described in Section 2.1.2.7.

Mammals and Birds

Alaska-Yukon Border to Whitehorse--This segment of the Fairbanks Corridor in Canada is about 270 miles long. It passes through Boreal Forest developed on relatively flat terrain close to the Alaska Highway. It crosses suitable habitat for moose, grizzly bear, black bear, wolf, red fox, lynx, weasel, beaver, muskrat, mink, shrews, rabbits and small rodents. Wolverine, marten, and otter probably occur in lesser numbers. The birds present include species typical of the Boreal Forest of northern Canada: gray jay, dark-eyed junco, ruby-crowned kinglet, yellow-rumped warbler, and many others. The Kluane Lake area is reported to be a staging area for waterfowl migration. Golden eagles are common, and other raptors such as the bald eagle, goshawk, sharp-skinned hawk, merlin, gyrfalcon, and peregrine are frequent to occasional visitors to the area of the proposed Kluane National Park.

Pelly Crossing to Whitehorse--Mule deer are found near Minto and moose occur along the entire route, but are probably most common in the Lake Laberge region. The Nordenskiold River lowlands may contain winter range for moose; high beaver and lynx populations are reported there as well as in the drainage of Kensha Creek. Populations of wolf, coyote, marten, mink, otter, red fox, black bear and some grizzly bear also occur along the corridor.

The bird fauna includes species typical of the northern Canada Boreal Forest: gray jay, dark-eyed junco, ruby-crowned kinglet, yellow-rumped warbler, and others. The Lake Laberge area supports a sizable population of diving ducks.

Whitehorse to Watson Lake--This segment generally parallels the Alaska highway near the base of Dall sheep habitat in the Big Salmon Range, and crosses Dall sheep and grizzly bear range in the Cassiar Mountains. Grizzly and black bear are occasionally sighted in the Teslin Lake area. Furbearers are well represented in areas along the route: the Marsh Lake area is noted for fox, lynx, mink, and wolverine; the Squanga Lake area for beaver; and the Swift and Rancheria River valleys for fisher. The Swift River area in British Columbia is also a winter area for moose.

A variety of birds occur along this segment of the corridor, but two areas are especially noteworthy: the Marsh Lake outflow is a production area for diving ducks and Nisutlin Bay in Teslin Lake is a stopping point for ducks, geese, and swans during spring and fall migrations.

Ecological Considerations

All comments made with respect to ecosystems of the Fort Yukon Corridor (Section 8.1.2.4) apply here. Additionally, the Haines Option Corridor to the Fairbanks Corridor, although it would not cross the Pacific Coastal Forest Ecosystem, might affect areas of the system which lie to the west of the corridor in British Columbia. The general features of ecosystems discussed for the proposed route also apply to this corridor (Section 2.1.2.8).

Economic Factors

The economic factors for the Canadian portion of the Fairbanks Corridor are generally similar to those given for the Fort Yukon Corridor. The Fairbanks Corridor in Canada is 2,826 miles long, part of which is essentially along or very close to the Alaska Highway between the Alaska-Yukon border near Beaver Creek and Dawson Creek, B.C. The portion that is described here lies between Beaver Creek and Watson Lake; southward from Watson Lake the corridor is identical with the Fort Yukon Corridor. The past and recent economic development of this portion of the Fairbanks Corridor area has been closely linked to mineral exploration and development (since 1897), routes of travel to Dawson and other mining areas, military activities, and to tourism, transportation, and related services (chiefly since 1946) along the Alaska (Alcan) Highway. The railhead at Whitehorse, connecting to tidewater, is of particular importance.

Mining produces the chief exportable commodities in this region; lead, zinc, copper, silver, gold, tungsten, nickel, and asbestos are of chief interest. Lead, zinc, copper, and asbestos have been the main products in recent years. Mining and mineral exploration are roughly centered in three areas: White River-Kluane Lake, Whitehorse, and Watson Lake. Many mines and prospects are not being worked at present, but are being actively explored or developed. No market exists within the region for the mineral commodities which are exported via Whitehorse. Coal deposits are known in the Whitehorse-Teslin area.

No statistics are available for the harvest of timber, game, fish and furs in this region. Presumably these commodities are of local importance but have only minor economic significance.

Employment and income throughout this region are chiefly wage oriented, and are heavily concentrated in and near Whitehorse. Approximately 2,600 people are employed in the wage economy in this region, as estimated from incomplete data. The employment is largely in many services, government, air, road and rail transportation, and mining and exploration. Data on the income characteristics are not available.

Details are not available for the tax structure and base. The Territorial Government has authority to tax developments outside of municipal limits, and the larger communities have some local taxing authority.

The economic trend in this area without the proposed pipeline project would be dependent on the level of activity in the government, tourism, and mining and mineral exploration sectors. Barring major changes, either favorable or unfavorable, in the mineral economy, the overall economy along this Alaska Highway route should continue to grow at a moderate rate comparable with the trend in the past several years which has been influenced by population growth and expanding governemnt, tourism and exploration activities.

Sociological Factors

The population characteristics of Yukon Territory have been reviewed in the discussion of the Fort Yukon Corridor (Section 8.1.2.4). Significant factors in the population growth along the portion of the Fairbanks Corridor between Beaver Creek and Watson Lake have been the opening and increasing use of the Alaska Highway since 1945, and the move of the Territorial capital from Dawson to Whitehorse in 1953.

The population in this corridor segment was approximately 12,500 in 1971; roughly 1,100 to 1,200 of this group are Registered Indians. About 11,000 people were in Whitehorse, compared to 3,500 in 1953 (Dominion Bureau of Statistics, 1953); this increase is in part due to a change in city boundaries.

Local government in the Indian communities is handled by an elected council and a Native band chief. The seat of Territorial government is in Whitehorse.

Houses and commercial buildings in the communities range widely in type and quality, but in general they are adequate and modern. Much new construction has been done in the past 15 years and a number of the older structures have been replaced. Whitehorse in particular has many new and modern public buildings, motels, and homes, and most of the small communities have at least one modern motel and some service facilities. Electricity is available from diesel plants in all communities and some hydropower is used in Whitehorse. No details are available in the Applicant's proposal on the foregoing items, or on the types and adequacy of other utility services, and health and educational facilities. Good medical and educational facilities are available in Whitehorse.

The trend in this region over the past 20 years has been one of rapid expansion of population and community facilities and organization in response to increased tourist, government and commercial activity. No future projections have been offered for the trends in these sectors, but it seems reasonable to assume that a more moderate rate of increase can be expected over the next 10 years if there are no major new economic developments.

Land Use

The principal human activities in most of the region traversed by the Fairbanks Corridor (including the Haines Option Corridor) are those commonly associated with surface transportation and tourism, including big-game hunting. The corridor, the Haines Option, and the part of the corridor that would be used by the Richards Island Supply Line if a gas pipeline were to occupy the Fairbanks Corridor, are all presently followed by highways. The Fairbanks and Fort Yukon Corridors coincide from Watson Lake southeastward; the coincident parts of these corridors are discussed in Section 8.1.2.4.

Paleontological, Archeological, and Historic

Scattered finds of fluted points document the presence of early man on the northwestern Alberta Plains shortly after the recession of the last glacier approximately 12,000 years ago. At this time, man probably hunted the now extinct megafauna. By about 8,000 years ago, conditions similar to the present became established in this area. In the central Yukon, spruce forests appeared about 8,700 years ago. Earliest archeological evidence from the Aishihik area indicates that man occupied this region approximately 7,200 years ago. During this time, both on the northern plains and in the intermontane area, bison was the major source of sustenance. Woodland caribou and elk were used less extensively in the mountains until about 5,500 B.C.

Developing out of this base, a subsequent cultural assemblage was characterized by a microblade and core technology associated with generalized hunting, fishing and trapping. Archeological sites attributable to this time period and cultural context have been found as far southwest as the Stikine River and as far southeast as Maxhamish Lake and Fort Nelson in British Columbia and Calling Lake in Alberta.

The period between 2,500 and 1,500 B.C. was one of climatic cooling and advancing valley glaciers in the intermontane region. Generally, a microblade technology persisted, although in some areas, more southerly plains-like influences in projectile points appeared. In the Aishihik area, microblade technologies continued until A.D. 300-500, when these culture-bearing horizons were terminated stratigraphically by the White River ash falls. Probably as a result of ecological disturbances from the ash fall, there was a marked decline in population in both the plains and intermontane regions. The archeological record of this period is characterized by a distinct decline in quality and quantity of lithic implements. On the Stikine River, the microblade technology was succeeded by forerunners of the historic Tahltan Indians; the northwestern Alberta Plains were then occupied by the Sekani Indians. Small side-notched projectile points are characteristic of archeological assemblages of this period.

Recreation and Esthetic Resources

From the Alaska-Yukon border to Haines Junction, the corridor follows the Shakwak Trench, which is one of the great valley features of the Cordillera and resembles the Rocky Mountain and Tintina Trenches in size and orientation. This valley is about 200 miles long and 10 miles wide, is occupied in part by Kluane Lake, the largest lake in Yukon Territory, and is bounded on the southwest by some of the highest mountains in Canada. From Haines Junction to Whitehorse, the Fairbanks Corridor crosses the relatively broad, rolling, forested valley occupied by the Dezadeash and Takhini Rivers. East of Whitehorse it follows the shoreline of Teslin Lake, with the rugged terrain of the Big Salmon Range in the background. Following the valleys of the Swift and Rancheria Rivers, it passes through the even higher and more rugged Cassiar Mountains, and then descends to Watson Lake in the center of the Liard Plain. From here on, the Fairbanks Corridor coincides with the Fort Yukon Corridor.

The proposed Richards Island Supply Line of the Fairbanks Corridor coincides with that of the Fort Yukon Corridor from Inuvik to Pelly Crossing. From there, it heads southeast to Whitehorse across the Yukon Plateau, following the existing all-weather highway across rolling, heavily forested terrain.

The Fairbanks Corridor passes close to or through Liard River Hotsprings Provincial Park, Muncho Lake Provincial Park, and Stone Mountain Provincial Park, and skirts the proposed new Kluane National Park. Recreation resources along this corridor are similar to those described for the Fort Yukon Corridor (see Section 8.1.2.4).

Air Quality

There are highways in practically the whole length of the Fairbanks Corridor. Because of exhaust emissions from mobile and stationary internal combustion engines, air quality is probably lower than in more remote areas in the region traversed and in areas in similar latitudes along the proposed route.

Environmental Noise

The general discussion of environmental noise along the proposed route (see Section 2.1.2.15) is applicable as well to the Fairbanks Corridor. Ambient sound levels are slightly higher than along the proposed route. Since the Fairbanks Corridor, including the supply line from Richards Island and the Haines Option, follows existing highways almost all of its length, existing noise levels are higher along a greater proportion of this corridor than for any of the other corridors and routes under consideration.

Evaluation of the Environmental Impacts

In contrast to the proposed, Interior, and Cross-Delta Routes, the Applicant has not furnished specific information on alignments, construction schedules, design, and numbers or locations of facilities in the Fairbanks Corridor. The absence of these data limits this impact analysis to general rather than specific comments. In the following discussions, it is assumed that (1) existing roads and material sites would be utilized wherever possible; (2) any pipeline would be located along the most favorable terrain within the corridor; (3) good engineering practice would be followed in all construction and maintenance operations; and (4) the impact of construction would be generally comparable to that of an oil pipeline.

Climate

The discussion of possible impacts on climate along the proposed route (Section 3.1.2.1) is applicable to possible impacts along the Fairbanks Corridor. Local and transitory ice fog, the only impact, would not be deleterious to the climate. If airstrips were not sited at elevations higher than equipment such as compressors, ice fog could interfere with aircraft movements for a few hours (or, rarely, a few days) before wind dispersed it. Total impacts of climate on a pipeline would be closely similar to those for the Fort Yukon Corridor (Section 8.1.2.4).

Topography

Potential impacts of construction of the proposed pipeline on topography are considered to be minor. Most of these would be secondary manifestations of more serious geologic impacts such as thermokarst development, gullying and stream siltation, and accelerated mass wasting. These topics are discussed in the following sections.

Geology

Use of Construction Materials

Construction of a pipeline and ancillary structures would require great quantities of sand and gravel or crushed rock for such purposes as pad foundations, backfill in trenches, and roadways. Suitable materials sources are generally abundant along the corridor, but are relatively scarce in some segments.

Alaska-Yukon Border to Whitehorse--Sand and gravel supplies are relatively limited through the 50 miles between the International Boundary and White River. Coarse alluvium probably is present in the valley floors of Beaver Creek and Snag Creek, but it appears to be mantled by thick peat, muck, and silt deposits in most areas. Extensive use of this alluvium could cause moderate to major environmental impact resulting from thawing of ice-rich permafrost, erosion of spoil piles, and influx of silt into stream systems. Water-washed glacial deposits, including outwash and ice-contact stratified drift, are present in morainal complexes south of Beaver Creek. However, these deposits are interspersed with till and other clayey or silty sediments, and are partly mantled with loess, lake deposits, and peat. Locally, they probably could serve as borrow sources without causing severe environmental impact. Their extensive use, however, might not be feasible because of such problems as overburden disposal, thermokarst formation, and accelerated erosion. Crushed rock obtained from Macauley Ridge, Eikland Mountain, and smaller knobs of resistant bedrock could provide abundant construction material to supplement the more limited sand and gravel. Aside from terrain disturbances along access roads, only minor environmental impacts would be anticipated from utilization of these sources.

Sand and gravel deposits are thick and abundant within portions of the Shakwak Trench northwest (for 70 miles) and southeast (for 30 miles) of Kluane Lake, and their utilization should generally cause only minor environmental disturbance in these areas. Minor to moderate impact, mainly resulting from stripping of vegetation and modifications of topography, would occur where sand and gravel were extracted from deep, stable, permafrost-free deposits such as alluvial fans, raised beaches and deltas of Kluane Lake, and the flood plains of streams which issue from unglaciated drainage basins. These deposits are abundant along the Shakwak Trench.

East of Kluane Lake, the thick lacustrine deposits of Shakwak Trench (30 miles) and Takhini Valley (90 miles) restrict most sand and gravel deposits to positions along the flanks of these troughs. Construction-materials sources include: (1) abandoned strandlines of glacial lakes; (2) alluvial fans near the mouths of tributary valleys; (3) local dune-sand deposits, especially near the community of Champagne (Kindle, 1953); (4) occasional glacial deposits such as kame terraces, outwash remnants, and moraines; and (5) talus and other coarse colluvium along range flanks. Outcrops of resistant rock types, especially the widespread granodiorite of the Coast Ranges, would be an additional source. Environmental impacts could range from minor to major, depending on borrow sites, amounts extracted, and mehods employed.

Richards Island to Campbell Lake--This segment of the Richards Island Supply Line coincides with a portion of the proposed route. Its environmental impacts are discussed in Section 3.1.2.3.

Campbell Lake to Pelly Crossing--This part of the Richards Island Supply Line coincides with a portion of the Fort Yukon Corridor. Its environmental impacts are discussed in Section 8.1.2.4.

Pelly Crossing to Whitehorse--Sand and gravel resources probably are abundant along most of the corridor between Pelly Crossing and Whitehorse. The valleys of the Yukon and Nordenskiold Rivers, and Klusha Creek should contain large quantities of coarse alluvium, ranging from glacial outwash to modern flood plain deposits. Postglacial stream incisions probably have caused many of these deposits to stand today as terraces well above modern flood plain levels. Borrow pits in such sites would usually cause little stream siltation or other environmental disturbance.

Sand and gravel resources may be sparse along about one-third of the 170 miles between Pelly Crossing and Whitehorse. The 35-mile segment that crosses the divide west of Lake Laberge may be underlain largely by ice-scoured bedrock or by thin patches of till. Glacial meltwater deposits probably are present, but their volume and character are unknown. The 20-mile divide crossing between Pelly River and Minto may have an even more limited amount of sand and gravel. Most of the alluvium may be buried beneath postglacial silt and muck deposits. Silt and muck, if widespread across the divide, would cause further problems of overburden disposal, stream siltation, and, probably, thermal degradation of permafrost wherever sand and gravel deposits were utilized.

Whitehorse to Watson Lake--Near Whitehorse, abundant sand and gravel supplies occur in alluvial terraces along a 25-mile segment of the corridor which follows the Yukon River. Utilization of sand and gravel here would probably cause only minor environmental impact.

More limited sand and gravel supplies may be present in the narrow valleys along the 30-mile stretch between Marsh Lake and Teslin Lake. It is unclear from available reports if alluvium caps glacial till here and if large postglacial alluvial fans are present.

Construction in the corridor segment along the northeast shore of Teslin Lake might be a particular problem. Except for occasional alluvial fans, this 40-mile segment may be largely underlain by till, colluvium, and lacustrine sediments. Exploitation of available sand and gravel deposits might cause siltation in Teslin Lake, which closely borders the corridor.

Construction materials probably are readily available east of Teslin Lake and across the Cassiar Mountains. Alluvium occurs widely on valley bottoms here, and stream entrenchment has caused ground-water tables and stream flood levels to be below the floors of most potential borrow pits. Where sand and gravel supplies are limited, additional sources of construction materials are present in the Pleistocene volcanic rocks east and west of the Cassiar Mountains and in the well-exposed granitic rock of the Cassiar batholith.

Alluvial sand and gravel are abundant along the 45-mile stretch within the Liard Plain, where stream entrenchment has caused many deposits to stand well above regional ground- and surface-water levels.

Watson Lake to Windfall, Alberta--This part of the Fairbanks Corridor coincides with the Fort Yukon Corridor (Section 8.1.2.4).

Haines Option Corridor--Construction materials appear to be widely available throughout the Haines Option Corridor. North of Chilkat Pass, the generally broad valley floors typically contain abundant deposits of sand and gravel in (1) eskers, outwash trains, and outwash fans; (2) fan-deltas around modern and ancient lake shores; (3) beach deposits; and (4) postglacial stream sediments. Streams are entrenched through much of this area, hence borrow pits could be emplaced above modern flood plains to avoid interaction with ground and surface waters.

Across Chilkat and Three Guardsmen Passes and south to the British Columbia-Alaska border, bedrock sources of crushed rock would be readily available but stream gravels may be a scanty source of borrow. Some suitable gravel deposits may occur in large alluvial fans.

Through the Alaska segment, which follows the glacier-fed Klehini and Chilkat Rivers, good quality sand and gravel supplies would be abundant. Material from borrow sites in the stream beds should be rapidly replenished by these rivers, and their high suspended loads should mean that water quality would be little affected by sediment entrainment caused by borrow mining.

Drainage Disruption

Alaska-Yukon Border to Whitehorse--West of Kluane Lake, the Fairbanks Corridor crosses the general northwardtrending drainage lines of the Yukon River basin, where many stream crossings would be required. Between the Alaska-Yukon border and Shakwak Trench, three relatively large streams (Snag, Beaver, and Dry Creeks) cross the corridor. Their broad silty flood plains, underlain by ice-rich permafrost, suggest that stream siltation could be a severe environmental problem. In the Shakwak Trench, three major rivers (White, Donjek, and Slims-Kluane) and many lesser streams flow northward across the corridor. Most have beds and banks of coarse gravel, providing favorable foundations for structures. Environmental hazards could be most severe where the corridor crosses the glacier-fed White, Donjek, and Slims Rivers. These streams are subject to great fluctuations in discharge, sudden and large channel shifts, and probably aufeis formation each winter.

East of Kluane Lake, the corridor parallels the courses of Dezadeash and Takhini Rivers. Only a single river crossing would be required by a pipeline routed near the Alaska Highway along the flank of Takhini Valley. This route also would cross most tributary streams on the gravel deposits of alluvial fans. Drainage disruptions caused by construction and maintenance of a pipeline and ancillary facilities would be minimal.

Richards Island to Campbell Lake--See Section 3.1.2.3.

Campbell Lake to Pelly Crossing--This part of the Richards Island Supply Line coincides with a portion of the Fort Yukon Corridor (Section 8.1.2.4).

Pelly Crossing to Whitehorse--Very few significant drainage effects would be anticipated from construction and operation of a pipeline between Pelly Crossing and Whitehorse. Virtually all of this possible route is along stream valleys, and parallels rather than crosses the main rivers of the region. Most stream crossings would involve small tributaries, and usually would be on alluvial fans near their mouths. These sites should present no unusual problems.

Most of the valley floors are broad enough so that any projected pipeline could be located at some distance from stream banks. Location of the route along the stable alluvial terraces, which are present along much of the corridor, would provide a further safeguard against drainage disruption.

If a pipeline were to follow the Klondike Highway through this region, major water crossings would be required at the following locations: (1) Takhini River about 10 miles north of Whitehorse, (2) Yukon River at Carmacks, and (3) Pelly River at Pelly Crossing.

In the absence of detailed surficial geologic studies, little can be said about potential environmental impacts of these three stream crossings.

Whitehorse to Watson Lake--Through most of its length between Whitehorse and Watson Lake, the corridor follows the axes of valleys and parallels their master streams. Major water crossings would be required at only four sites: (1) Yukon River north of Marsh Lake, (2) Teslin River at Johnsons Crossing, (3) Nisutlin Bay at Teslin, and (4) Rancheria River about 50 miles west of Watson Lake. Sand and gravel banks probably are present at most of these crossings, and permafrost probably is absent. Although nearly 70 lesser stream crossings would be necessary, these usually would be on the alluvial fans of small tributary streams. None of the stream crossings along this part of the corridor would be likely to cause serious geologic impacts.

In the narrower mountain valleys, such as those west and east of Teslin Lake, active river flood plains occupy nearly all of the valley floors. This seriously restricts the areas available for pipeline construction, and would cause potential problems such as (1) bank erosion and flood threats to a pipeline, (2) stream siltation resulting from construction and maintenance operations, and (3) pollutants entering the drainage systems.

As described in previous sections, where the corridor skirts the shores of Kluane Lake, Marsh Lake, Teslin Lake, and several smaller water bodies, it is compressed into a narrow zone with a lake on one side and a steep valley flank on the other. Silt influx into lake water would be a potential problem if a pipeline were to be constructed.

The extent and frequency of aufeis formation along the Fairbanks Corridor is unknown. Icings induced by construction and operation of a pipeline could be a problem in some areas, especially if active subsurface water flow within alluvial fans were to be dammed by a cylinder of frozen ground around a cold-gas pipeline.

Watson Lake to Windfall, Alberta--This part of the Fairbanks Corridor coincides with the Fort Yukon Corridor (Section 8.1.2.4).

Haines Option Corridor--Construction of a pipeline in the Haines Option Corridor would generally have little impact on drainage. The route segment between Haines Junction and Dezadeash Lake crosses the broad floor of Shakwak Valley, and generally is remote from surface streams. Within the alpine valleys farther to the south, the corridor generally parallels the larger streams and crosses tributaries on massive alluvial fans. Gravel beds and banks are probably present at all stream crossings, decreasing the hazards of erosion and siltation. In Alaska, the corridor follows the large glacier-fed Klehini and Chilkat Rivers. It is unlikely that construction or maintenance operations could affect these rivers in any significant way.

The 10-mile stretch of the corridor skirting the west shore of Dezadeash Lake is considered to present the greatest potential hazard to surface waters in the region. The corridor here is very narrow, hence construction and maintenance operations would take place near the lake shore. Slope angles become fairly high close to the south end of the lake, where the corridor would be narrowest. Accelerated erosion or mass wasting could cause significant silt influx into the lake. The steep front of the Kluane Ranges rises directly above the corridor in this stretch, presenting the added hazard of rupture of a pipeline by landslides, avalanches, or other catastrophic mass movements. In such an event, water quality of Dezadeash Lake could be damaged by pipeline debris carried into the lake by the mass-wasting processes and by effects of large-scale emergency repair operations.

Disposal of Excess Spoil

Little can be said about possible problems resulting from excess spoil without detailed information on routing, locations of support facilities, and other engineering aspects of a pipeline within the Fairbanks Corridor.

In general, excess spoil of unstable character would likely be generated by construction activities in the area between the Alaska-Yukon border and the White River. Silty and clayey spoil also is a potential problem in Takhini Valley, but its severity there would depend largely upon whether structures were located near the valley center or along its north flank.

Along most other sectors of the corridor, excess spoil usually will tend to be gravelly in character. Some should be usable for fill or pad foundations; much of the remainder might be suitable filling material for abandoned borrow pits.

Thawing of Permafrost

Alaska-Yukon Border to Watson Lake--As pointed out by Ferrians (1974), even a cold-gas pipeline is subject to problems of permafrost thaw resulting from construction activities and from further thaw of the disturbed soils between the construction and operation phases.

Permafrost problems would be relatively severe between the Alaska border and White River where ice-rich shallow permafrost appears to be most widespread. Thaw lakes are common in several localities, suggesting that thaw settlement might be a significant problem. Ice wedges may also be abundant, and extremely uneven settlement might take place following removal of plant cover or other disturbance of these localities. The corridor crosses gentle to moderate slopes through much of this segment, and slope problems such as flowage of saturated soils and erosion by permafrost meltwater might also be anticipated.

Permafrost is relatively limited in occurrence farther to the east. Although its exact extent is unknown, it is estimated to be neither extensive nor deep. Along most parts of this corridor segment, permafrost probably could be avoided by routing a pipeline through the more granular and better drained soils. Most permafrost encountered would likely be in bogs or other small depressions; it would cause no major slope erosion problems, and negligible siltation of streams. Permafrost hazards might be most severe in clayey, silty lake deposits where these occurred on slopes or cropped out along the faces of alluvial terraces.

Watson Lake to Windfall, Alberta--This part of the Fairbanks Corridor encounters very little permafrost.

Richards Island to Campbell Lake--This segment of the Richards Island Supply Line coincides with a portion of the proposed route (see Section 3.1.2.3).

Campbell Lake to Pelly Crossing--This part of the Richards Island Supply Line coincides with a portion of the Fort Yukon Corridor (see Section 8.1.2.4).

Pelly Crossing to Whitehorse--The gravelly flood plain stretches and alluvial terrace remnants along major valleys should cause few permafrost problems along about 90-100 miles of this corridor segment. The divide area west of Lake Laberge might contain thicker and more abundant permafrost, but environmental effects of permafrost disturbance and thaw cannot be assessed without detailed knowledge of the surficial geology.

The greatest permafrost problem would probably be in the 20-mile stretch between Pelly Crossing and Minto where ice-rich permafrost possibly is abundant in silt and muck deposits. Potential problems would include development of thaw gullies on slopes, differential subsidence beneath pipeline facilities, accelerated soil flowage, and siltation of rivers and streams.

Accelerated Erosion and Mass Wastage

Areas subject to erosion and mass wasting were identified and discussed previously under Mass Wasting and Erosion. Most of these same areas would be subject to accelerated slope processes as the result of pipeline-related activities. Additional areas of concern would be those of greatest potential drainage disruption and those where ice-rich permafrost is abundant in fine-grained sediments. Particularly critical localities should lie within each of the route segments listed below:

Alaska-Yukon Border to Watson Lake

1. Zone of relatively widespread permafrost between the Alaska-Yukon border and White River.

2. Shores of Kluane, Marsh, and Teslin Lakes, where the corridor is compressed between lake and steep mountain flank.

3. Lacustrine deposits in Takhini Valley, and in the troughs occupied by Yukon and Teslin Rivers.

4. Narrow, steep-sided valleys east and west of Teslin Lake.

Richards Island to Campbell Lake

See Section 3.1.2.3.

Campbell Lake to Pelly Crossing

See Section 8.1.2.4.

Pelly Crossing to Whitehorse

1. Divide between Pelly Crossing and Minto, where ice-rich permafrost probably is widespread within silt and muck deposits.
2. Areas of deep entrenchment along the Yukon River and its tributaries.
3. Areas where the Yukon River and its tributaries are cutting laterally into unconsolidated deposits.
4. The divide crossing west of Lake Laberge.

Haines Option Corridor

1. Lacustrine sediments of Glacial Lake Champagne, especially along steep bluff or terrace faces created by deep postglacial stream incisions.
2. West shore of Dezadeash Lake.
3. Steep narrow glacial valley segments between Three Guardsmen Pass and the International Boundary.
4. Areas of elevated marine clays near Haines.

Hazards to the Pipeline

The following sections discuss potential geologic hazards to a pipeline that might utilize the Fairbanks Corridor. These are the hazards that could result from seismic, glacial, or volcanic activities. Other geologic hazards resulting from erosion, mass movements, and thawing of permafrost were evaluated in preceding sections.

Earthquakes and Active Faults--Seismic hazards are considered minor to moderate along most of the Fairbanks Corridor. The Haines Option Corridor is subject to far greater seismic risk, which is intensified by coastal hazards such as seismic sea waves.

Through the Shakwak Trench, the corridor is parallel to the Shakwak Fault for about 130 miles and may intersect other faults which cross or enter the trench. Displacements along Shakwak Fault at the south flank of the trench apparently have taken place during the Holocene, but there is no record of movement during historic time. However, several earthquakes of magnitude 5 to 6 have been recorded in the vicinity of this fault (Lemke and

Yehle, 1972). A pipeline routed down the northern to central part of Shakwak Trench should be subject to very little seismic disturbance. A route along the south flank of the trench might be endangered by fault movements and would be subject to the risk of rock falls, rock and debris avalanches, slides, and other rapid mass movements triggered by earthquake vibrations. Special earthquake design considerations would be required if a pipeline were to skirt the south shore of Kluane Lake and enter the Shakwak Fault zone near the Slims River Bridge of the Alaska Highway. Here the pipeline would be forced against the base of steep, potentially unstable mountain slopes accentuating seismic risk through the possibility of vibration-triggered sudden mass movements.

East and west of the Shakwak Trench, seismic hazards along the corridor are negligible. The sections from the Alaska-Yukon border to White River and from Whitehorse to Watson Lake lie within regions of low seismicity. No active faults have been mapped by geologic field parties in this region, and none of the available geologic maps show faults cutting late Pleistocene or Holocene sediments.

The Richards Island Supply Line crosses the Richardson Mountains seismic zone, described in Section 8.1.2.1. An estimated 50-mile stretch of the supply line would be subject to a maximum expectable earthquake of magnitude 7. South of the Richardson Mountains the corridor crosses a region of low seismicity. No active faults are known to occur here, and published maps show all fault lines in bedrock terminating at the margins of Quaternary deposits.

The most severe seismic hazards would probably occur in the Alaskan sector of the Haines Option near the community of Haines. This area is a high-seismic-risk zone because of (1) possible occurrence of active faults, (2) a history of earthquakes, (3) presence of steep unstable slopes, (4) presence of sensitive marine clays, and (5) seismic sea-wave hazard.

The Chilkat River fault parallels the corridor between Klukwan and Haines, and probably lies within a mile of it through much of this distance. Current microseismic activity along the fault suggests that it may still be active (MacKevett, Robertson, and Winkler, 1974). An earthquake of magnitude 6, possibly centered on this fault, occurred in Chilkat Valley about 10 miles from the corridor in 1952 (Lemke and Yehle, 1972). Although no other large historic earthquakes have been located close to the corridor, the general Haines region is characterized by high seismicity. Since 1847, more than 100 earthquakes ranging from slight tremors to severe shocks have been felt and reported in Haines (Lemke and Yehle, 1972).

Anticipated effects of strong earthquakes in the Haines area would include (1) surface displacement on faults; (2) ground shaking; (3) compaction, subsidence, and fracturing of sediments; (4) liquefaction of saturated sands and silts; (5) flowage of sensitive marine clays; (6) subaerial slides and slumps; (7) subaqueous slides; and (8) tsunamis, seiches, and other abnormal water waves (Lemke and Yehle, 1972, p. 67-90). All of these hazards would have to be considered in the location and design of any pipeline within the Haines area.

Glacial Hazards--Several surging glaciers in the northern parts of the St. Elias Range terminate close to Shakwak Trench. Steele Glacier, in the Donjek drainage system, extends to within about 25 miles of the trench. It last surged during 1965-68, when it advanced about 10 miles. Klutlan Glacier, in the White River drainage system, lies 23 miles south of the trench. Deformed moraines on its surface suggest a past history of surging. Direct advance of surging glaciers into Shakwak Trench is unlikely, because most surges extend only 5-10 miles and usually terminate within a glacier's own dead-ice zone. Rapid ice wastage following a surge could be a greater problem along the corridor, possibly leading to erosion, flooding or rapid outwash deposition along the White and Donjek Rivers.

Damming of Alsek River by Lowell Glacier was described previously. This event caused flooding of Shakwak Trench twice during the past 250 years, and could occur again. Kindle (1953) reported that Lowell Glacier was within 100 feet of damming the Alsek River in 1951, although it was relatively thin at that time and could not have created an extensive lake. Subsequent changes in the glacier's thickness and extent are unknown.

Post and Mayo (1971) show several small lakes and former lake beds in ice-free valleys blocked by the Donjek and Steele Glaciers. Growth of ice-dammed lakes there, followed by their sudden release, could cause glacier-outburst floods down the Donjek River and across Shakwak Trench.

Volcanism--Fresh-appearing volcanic and volcaniclastic rocks occur along the Fairbanks Corridor in Shakwak Trench and in several places between Teslin and Watson Lakes. These volcanic units are of late Quaternary age and in two sites even postdate the last glaciation of the region. Associated volcanic centers are possibly dormant rather than entirely extinct.

Mineral Resources

Metallic and Nonmetallic Mineral Resources--Other than the consumptive use of construction materials, the construction and operation of a gas pipeline in the Fairbanks Corridor, including the Haines Option and a corridor for the part of the Richards Island Supply Line between the Pelly River and Whitehorse, would have no impact on metallic or nonmetallic resources and their extraction. The area is already served by transportation facilities (Figures 8.1.2.4-2 and 8.1.2.5-2) that are adequate for the foreseeable needs of the minerals industry, so the possible additional accessibility that might be brought about by the construction of pipeline-related facilities would be unimportant.

Oil and Gas--A gas pipeline across the Bowser basin would make it possible to recover small accumulations of gas, but the low probability of finding new reserves should limit exploration. The effect on oil and gas resources along the remainder of the Fairbanks Corridor would be the same as that described for the Fort Yukon Corridor.

Soils

Trenching and other pipeline construction activities would impact topsoils along the Fairbanks Corridor to a variable degree ranging from complete destruction to partial burial by addition of thin layers of excavated subsoils and soil parent material. In addition, there would be extensive mixing of topsoils with low-nutrient subsoils and parent material from the pipeline trench. Because most subsoil and underlying geologic materials that are likely to be excavated generally are not well suited for plant growth, revegetation measures might have to be repeated several times before successful plant growth and ground stabilization could be obtained.

A potential for wind erosion and water erosion of soils that would be exposed during construction exists along the entire route. In permafrost areas disturbance of some soils during construction might, in conjunction with differential thawing of permafrost, cause a decrease in terrain stability and a ponding and channeling of surface waters. In non-permafrost areas, disturbance of topsoils might alter surface drainage and increase erosion; locally, desiccation of topsoils might occur.

The Fairbanks Corridor would not cross major areas of agricultural lands; thus there is little potential for major impact on agricultural uses of soils.

Water Resources

The degree of potential impact at stream crossings would depend upon the design and the measures taken during construction to minimize the impact. Four areas of concern are: (1) channel erosion, (2) icings, (3) depletion of streamflow during construction, and (4) drainage disruption (see Table 3.1.2.5-1 for a general summary of impact mechanisms and possible consequences).

The primary impact on ground water by the pipeline would be the disturbance of the shallow active layer overlying permafrost during pipeline construction and operation (see Figure 3.1.2.5-1b). Disturbance of the thermal regime in the active layer would create new ground-water flow patterns, possibly resulting in aufeis, accelerated thermal degradation, accelerated erosion, frost heaving, and potentially explosive icing mounds. Another potential for impact on ground water would be the discharge of liquid wastes and leaching of sanitary landfills.

Vegetation

Corridor Segment Impacts

Campbell Lake to Pelly Crossing--See Fort Yukon Corridor (Section 8.1.2.4).

Pelly Crossing to Whitehorse--This segment, although essentially of wilderness quality, follows the Klondike Highway and is readily accessible. Discontinuous permafrost is widespread and river crossings would be potentially disruptive to vegetation. The principal impact on vegetation would be the clearing of the highly productive white spruce and lodgepole pine forests along the right-of-way crossing of lower slopes and valley bottoms.

Alaska-Yukon Border to Watson Lake--The Fairbanks Corridor would follow the Alaska Highway throughout this segment. Discontinuous permafrost is present although not widespread southeast of Whitehorse where it occurs in organic terrain, on north-facing slopes, and at higher altitudes (CAGPL, 1974e, p. 27). There would be numerous stream crossings with potential slope instability but the principal impact on vegetation would result from clearing of the right-of-way in the open, parkland forests of spruce and mixedwoods and the permanent occupancy of land for compressor stations and other facilities.

Haines Option Corridor--The Corridor extends about 160 miles from Haines Junction, including 45 miles within Alaska. The Canadian segment of right-of-way and related pipeline facilities would cross or otherwise affect three vegetation formations. Boreal Forest probably would be crossed for about 80 miles and Alpine Tundra for about 35 miles. The 45-mile segment in Alaska would lie partly in Alpine Tundra but mostly within Western hemlock-Sitka Spruce Forest of the Pacific Coastal Forest Formation. The principal impact would be the removal of forest trees for the duration of the pipeline operation.

Major Plant Communities Affected

Fairbanks Corridor--The total Corridor length to delivery points at the Canada-U.S. border is 2,826 miles (Table 8.1.2.9-1). It would affect a total of 50,070 acres of vegetation. The portion treated here includes the corridor only as far as Windfall, Alberta, a right-of-way length of 1,986 miles.

The Richards Island Supply Line crosses Low Shrub-Heath Tundra, Alpine Tundra, Forest-Tundra, and Boreal Forest communities. The corridor from the Alaska-Yukon border to Windfall lies within the Boreal Forest, except about 40 miles of Aspen Parkland.

Based upon the averages of right-of-way and facilities acreages per mile (Table 8.1.2.9-1), vegetation would be affected approximately as follows:

	Right-of-way	Facilities	Total
Low Shrub-Heath Tundra	1,269	286	1,555
Alpine Tundra	1,804	408	2,212
Forest-Tundra	3,564	804	4,368
Boreal Forest	21,439	4,839	26,278
Aspen Parkland	577	130	707
Total	28,653	6,467	35,120

Haines Option Corridor--The acreage of vegetation affected along the 115 miles of corridor from Haines Junction, Yukon Territory, to the British Columbia-Alaska border would be approximately as follows:

	Right-of-way	Facilities	Total
Boreal Forest	1,154	260	1,414
Alpine Tundra	505	114	619
Total	1,659	374	2,033

The 45-mile segment of this corridor in Alaska would probably cross some alpine tundra but would principally lie within the Pacific Coastal Forest Formation. About 800 acres of vegetation would be affected by right-of-way and facilities in addition to the unknown land requirements for an LNG plant.

Wildlife

Fish

Because of the rugged terrain and steep-gradient streams, a pipeline following the Fairbanks Corridor would be likely to cause more turbidity and siltation than one following the proposed route. Insufficient background material is available to permit evaluation of impact of possible use of this corridor on fish and fish habitats. It is expected that the impacts would generally be the same as those of the Fort Yukon Corridor, but with less effect on wilderness which for a greater portion of the traverse has already been affected by highways.

Mammals and Birds

Alaska-Yukon Border to Whitehorse--This segment of the Fairbanks Corridor has low relief and is relatively close to the Alaska Highway. A total area of more than the 6 square miles on the right-of-way would be disturbed, but most of this area, through reseeding or succession, would eventually be revegetated. For many small mammals, such as rodents, weasels, and shrews, the construction of a pipeline would represent a temporary loss of habitat, in contrast to permanent habitat loss accompanying the highway construction. Adverse impacts on mammals, because of the damage already done by the highway, would generally be less than those along routes through areas not previously disturbed. Anticipated impacts on birds would be similar to those on mammals. There would be some habitat loss from clearing of the right-of-way. For some species, particularly waterfowl, spills of fuel oils or testing fluids would pose additional hazards.

Pelly River Crossing to Whitehorse--This portion of the Richards Island Supply line for the Fairbanks Corridor is not common to the alternative routes previously discussed (Sections 8.1.2.1; 8.1.2.4). This section passes through good beaver and moose habitat, and, while not close, is generally accessible from an existing highway. The adverse impact would extend beyond the area of land actually disturbed by the pipeline right-of-way (3.5 square miles) depending upon species and distance from the highway. Larger mammals would tend to be affected more than small ones. Moose habitat along the Nordenskiold River may include critical winter range for this species. In addition to effects of clearing the right-of-way, the food base for diving ducks in the Lake Laberge area could be affected adversely by siltation or spills of fuel oil or testing fluids.

Whitehorse to Watson Lake--This segment of the Fairbanks Corridor generally parallels the Alaska Highway. In addition to direct losses of habitat amounting to approximately 6 square miles and impacts that would be similar to those along the segments discussed above and in Section 8.1.2.4, there would be several additional impacts on mammals along the Whitehorse to Watson Lake segment. The Big Salmon Range and Cassiar Mountains include Dall sheep and grizzly bear range but there is no indication that any critical habitat would be affected. Furbearers are well represented in the corridor and some impacts from increased human activities, including trapping, would be expected. The Swift River area is moose winter range, but how much critical winter range would be disturbed is unknown.

In addition to the bird habitat along the right-of-way that would be lost or altered, there are two areas of importance to waterfowl: the Marsh Lake outflow area for diving ducks and Nesutlin Bay on Teslin Lake where large numbers of ducks, geese, and swans assemble in spring and fall during migration. Additional disturbances of these populations and of their food-base organisms are possible adverse impacts, but information is inadequate to determine the extent and the degree of the potential impact.

Other segments, Watson Lake to Windfall and Campbell Lake to Pelly Crossing, are common to both the Fairbanks and Fort Yukon Corridors. They are described in Section 8.1.2.4. The corridor segments, Richards Island to Campbell Lake, and Windfall to the United States-Canada border comprise the proposed route as well as parts of other alternatives. These are described in Section 3.1.2.7.

Ecological Considerations

The general nature of impacts of the proposed pipeline on ecosystems has been discussed for the proposed route (Section 3.1.2.8) and all comments apply to this Corridor.

Economic Factors

If a pipeline were built along the Fairbanks Corridor, the total route distance in Canada would be 391 miles longer than along the proposed route. Therefore, the proportionately greater amounts of time and labor required would generate somewhat more economic impact than would be expected from the proposed route.

The factors of employment, income, and gas supply to communities close to the Fairbanks Corridor would be similar to those mentioned for the Fort Yukon Corridor (Section 8.1.2.4). Some economic differences would be introduced by the larger concentration of population and therefore gas market in the Whitehorse area, the greater distance of the Fairbanks Corridor from some established mines, and by the coincidence over the entire Fairbanks Corridor with the route of the major Alaska Highway.

No figures are given for local taxes and tax bases, but it seems inevitable that the proposed construction and operation activities, if in the Fairbanks Corridor, would contribute significantly to tax revenues of at least the eight established communities directly along the corridor.

The infrastructure already existing along the Alaska Highway would be, in varying degrees, already able to support additional activities, and it is probable that upgrading and expansion of existing facilities could be accomplished easily. Increased economic activity should work to the advantage of any existing businesses that currently might be marginal.

Sociological Factors

The approximate 12,500 population along the Fairbanks Corridor was distributed in 1972-1973 as follows: Whitehorse 11,100, Watson Lake 555, Teslin 340, Haines Junction 190, Carcross 190, Beaver Creek 120, Burwash Landing 65, Destruction Bay 80. No projection of the future trend is offered by the Applicant. It is reasonable to assume that, if the proposed pipeline were built in this corridor, there would be a moderate population increase, at least temporarily, in addition to that which could be projected in the absence of any major new project. This would be generated by increased demands for services and recreation. The continuing need for an operational staff for the proposed pipeline could result in increased employment for the local residents or a migration of people from other areas seeking jobs, or both.

The impact of the project on housing and secondary service facilities is difficult to assess in the absence of a survey of existing facilities. The quantity and quality of existing housing in this region is probably no more than adequate for present needs, and that more housing would be needed to accommodate even a small population increase. The need for more or better service facilities would vary depending on the communities and particular business. Expansion of at least some facilities would be needed in many of the communities.

Land Use

General land-use patterns would be little changed if a gas pipeline were to be constructed in the Fairbanks Corridor. The major impact during the life of the project would be the dedication of sites for compressor stations, some borrow pits, and communications facilities to pipeline-related uses for the duration of the project. Impacts during construction would include withdrawal of the right-of-way from other uses as well as use for borrow pits and quarries that would not be needed for maintenance. Additional possible impacts during construction would be crowding of existing highways by additional traffic and changes in breeding and foraging habits of game animals, both of which might affect tourism.

Paleontological, Archeological, and Historic

Because so little information on archeological aspects of the Fairbanks Corridor is available, it is difficult to predict the impact of pipeline construction on the archeological resources of the region. Of course, all phases of construction involving land use could cause loss of, or damage to, archeological and historical resources. Construction of ancillary features such as compressor stations, borrow pits, stockpile sites, and wharves, as well as the excavation of a pipeline trench itself, could destroy potential archeological and historic sites.

Construction of a pipeline along this corridor would not appreciably increase the accessibility of archeological and historic sites because the proposed corridor roughly parallels for most of its length, existing roadways such as the Dempster Highway and the Alaska Highway.

While construction of a pipeline could destroy potential archeological sites, it could also uncover some sites, which could be salvaged by professionals. Any new information thus obtained would probably contribute greatly to knowledge of the prehistoric inhabitants of the region.

Recreation and Esthetic Resources

Because this corridor coincides with the Fort Yukon Corridor over much of its length, the impact of pipeline construction along it would be similar to that of the Fort Yukon Corridor (see Section 8.1.2.4). The Fairbanks Corridor is roughly parallel to existing or planned roads for nearly all of its length, so pipeline construction in it would have a visual impact on highway travelers. Pipeline construction along the Fairbanks Corridor would have some visual impact on the proposed Kluane National Park.

Air Quality

Construction and operation of a gas pipeline in the Fairbanks Corridor would have the same types of impacts on air quality as if the proposed route were followed (Section 3.1.2.14). Pollutants from internal combustion engines used for pipeline construction, operation, and maintenance would be in addition to similar emissions from vehicles on highways and stationary sources in settlements and probably would not in themselves be obvious. All pollutants would probably be rapidly dispersed.

Environmental Noise

The noise emissions along the Fairbanks Corridor will be similar to those along the proposed route, as discussed in Section 3.1.2.15. However, because existing highways occupy the corridor most of its length, the addition of construction noise may constitute less of an impact than on much of the proposed route. On the other hand, the Fairbanks Corridor has a higher resident and transient population than much of the proposed route, and many of these individuals may find the added construction noise, and, locally, the noise of the continuously operating compressor stations during the operational phase, sufficiently annoying that it would constitute a significant noise impact.

The differences in the noise impact on wildlife between this route and the proposed route will be a result of the differences between the numbers of seasonal locations of wildlife along the 2 routes.

8.1.2.6 Offshore Corridor

An offshore alternative pipeline corridor described by the Applicant (AAGPC, 1974, V, 1.3, 34 p.) would be 222.2 miles long roughly paralleling the Arctic coastline north of the National Arctic Wildlife Range in northeastern Alaska (Figure 8.1.2.6-1). In large part a pipeline built in this corridor would be an underwater pipeline off the Alaska Coast. Approximately 20 miles of the Corridor would be on land in the extreme northwest corner of Canada where it would join the proposed route at Milepost 213.2.

Because only a small portion of the Offshore Corridor is in Canada, the complete description is presented in the Alaska volume of this Statement.

8.1.2.7 Southern Canada Corridors

Three corridors that could serve as alternatives to the southern part of the proposed route are discussed in this section: 1) the Wolf Lake Corridors, 2) the Dome Corridor, and 3) the Brandon Corridor. Only the first of these was suggested by the Applicant; the other two are designed to connect with alternative corridors developed in the conterminous United States. The names given here are used for convenience in this description and were not provided by the Applicant.

The Wolf Lake Corridors would be an alternative to the proposed route south of Milepost 684. North of this point, the Wolf Lake Corridors coincide with the proposed route to Alaska-Yukon border and to Richards Island. The corridors could alternatively be connected to either the Interior or the Cross-Delta Route. "Wolf Lake Corridors" is a collective appellation for separately named corridors, the Liard River-Wolf Lake Corridor, the Wolf Lake-Emerson Corridor, and the Wolf Lake-Crowsnest

Corridor, which are analogous respectively to the Main Line, Monchy Delivery Line, and Kingsgate Delivery Line of the proposed route (Figures 8.1.2-1 and 2, and 8.1.2.7-1, 2, 3, and 4).

The Liard River-Wolf Lake Corridor extends southeastward across southern Northwest Territories and northern Alberta for 618 miles, from the proposed route near the mouth of the Liard River to a point near Wolf Lake in eastern Alberta, here termed Wolf Lake Junction. The Wolf Lake-Emerson Corridor continues southeastward across Alberta, Saskatchewan, and southwestern Manitoba for 717 miles, from Wolf Lake Junction to Emerson, Manitoba, where it would join the Red River Corridor in adjacent Minnesota (see North Border volume this Statement). The Wolf Lake-Crowsnest Corridor extends southwestward across Alberta for 385 miles, from Wolf Lake Junction to Crowsnest Pass on the Alberta-British Columbia border where it would join the proposed route at Milepost 173 on the Kingsgate Delivery Line and continue to the U.S.-Canada border.

The Dome and Brandon Corridors would be alternatives to the southeasternmost part of the Monchy Delivery Line of the proposed route (Figure 8.1.2.7-5). They could thus be used in conjunction with the proposed route or the Interior or Cross-Delta Route or the Fort Yukon or Fairbanks Corridor. They would closely parallel existing or proposed pipelines.

The Dome Corridor is about 401 miles long and consists of two segments: 1) the Moose Jaw segment which extends eastward across southern Saskatchewan for 218 miles from the Alberta-Saskatchewan border where it diverges from the proposed route at Milepost 234 to a point near Keystone, Saskatchewan, and 2) the Dome segment which extends southeastward for 183 miles from near Keystone to the U.S.-Canada border near Elmore, Saskatchewan, where it would join the Dome Route in the United States (North Border volume, this Statement).

The Brandon Corridor is about 695 miles long and consists of three segments: 1) the 218-mile Moose Jaw segment, identical to that of the Dome Corridor; 2) the Brandon segment, which extends eastward for 233 miles from near Keystone, Saskatchewan, to a point near Moorepark, Manitoba, where it would join the Wolf Lake-Emerson Corridor; and 3) the Treherne segment of the Wolf Lake Corridor, the southeasternmost 137 miles of that corridor extending from Moorepark southeastward to Emerson. The Brandon Corridor like the Wolf Lake Corridors, would thus also connect with the Red River Corridor in the United States.

Description of the Existing Environment

Climate

Data presented in the discussion of the climate of the proposed route (Section 2.1.2.1) probably are generally applicable to the Southern Canada Corridors.

Topography

The description of topography given below for the three Wolf Lake Corridors was developed from information based principally on maps in the Atlas of Alberta (Government of Alberta, 1969), the Atlas of Saskatchewan (Richards and Fung, 1969), and the map, Physiographic Regions of Canada (Bostock, 1970). Data for the Dome and Brandon Corridors are based on analysis of 1:250,000 scale maps of the Canada National Topograpny System.

The Wolf Lake Corridors have been subdivided, topographically, on the basis of the drainage basins that they traverse. Elevations are given for high and low areas within each drainage basin; distances are approximations accurate to within about 10 miles.

Slopes (Table 2.1.2.2-1) along the Wolf Lake Corridors probably are in general nearly flat to gentle; only scattered areas of moderate to moderately steep slopes occur and steep to very steep slopes are found mainly at crossings of major streams. Slopes may be several hundreds of feet high at crossings of major streams but slopes are generally less than 100 feet at most other stream crossings.

Liard River-Wolf Lake Corridor

Most of the corridor lies in the Mackenzie River drainage system which leads to the Arctic Ocean, but the last 13 miles drains to Hudson Bay via the Beaver and Churchill Rivers.

The first 148 miles of the corridor lies in the Northwest Territories, in the drainage basin of the Mackenzie River itself, crossing the basins of several tributaries. The beginning of the corridor marks the lowest elevation in this segment, and of the entire Wolf Lake Corridors system, 525 feet above sea level. The elevation along the corridor generally rises to the southeast, reaching over 2,000 feet above sea level at the Northwest Territories-Alberta border.

In Alberta most of the length of the corridor remains in the drainage basin of the Mackenzie River. The corridor crosses the Petitot River, a tributary to the Liard River, at about 1,800 feet above sea level. Elevations rise to over 2,000 feet in the Cameron Hills. The corridor then crosses several major drainage basins tributary to the Mackenzie system. The first basin is that of the Hay River; all of the elevations are under 2,000 feet above sea level. The Hay River and the Mackenzie Highway are crossed at an elevation of about 1,000 feet, the lowest elevation in this basin. The next drainage basin crossed is that of the Peace River between about 255 and 480 miles from the beginning of the corridor. Most of this stretch lies below 2,000 feet in elevation, but some of it reaches to about 2,000 feet in a few places, and at the end it climbs above 2,000 at a high part of the Algar Plain where there is an area of internal drainage. The Peace River is crossed at an elevation below 1,000 feet; the Boyer River also is crossed in this general vicinity. For over 100 miles the corridor then follows the valley of the Wabasca River, a tributary of the Peace River.

From about 480 to 605 miles from the beginning of the corridor the Athabasca River drainage basin is crossed. The Athabasca River itself is crossed at about 1,100 feet above sea level. Southeast of the river crossing, the corridor lies generally above 2,000 feet in elevation.

For the last 13 miles, to its end at Wolf Lake Junction, the corridor lies in the Beaver River drainage basin which drains into Hudson Bay via the Churchill River. Most terrain is slightly over 2,000 feet in altitude throughout this stretch with the low point probably being the end of the corridor where the Sand River is crossed at about 2,000 feet above sea level.

Wolf Lake-Emerson Corridor

All of the area crossed by this corridor drains to Hudson Bay. Maximum elevation is over 2,400 feet and the minimum is under 800 feet; elevations generally become lower toward the southeast.

All of the corridor in Alberta lies in the Beaver River drainage basin; the low elevation occurs at the crossing of the Beaver River about 25 miles from Wolf Lake Junction. At the Alberta-Saskatchewan border the corridor lies just over 2,000 feet in elevation.

In Saskatchewan the corridor continues in the Beaver River drainage basin for about the next 130 miles. Elevations are above 1,800 feet for most of this stretch, dropping to just below 1,800 feet at the crossing of the Makwa River, a tributary to the Beaver. The elevations rise to a high point of over 2,400 feet. From 190 to 275 miles from Wolf Lake Junction, the corridor lies in the basin of the North Saskatchewan River and is mostly between 1,500 and 1,800 feet in elevation, rising to over 1,800 feet only in the southeastern end of this stretch. The low points are just below 1,500 feet at the crossings of the North Saskatchewan and the South Saskatchewan Rivers. For the next 40 miles there is an area of poorly organized internal drainage that ranges in elevation from over 2,100 feet to just about 1,800 feet. The following 5 miles is within the drainage basin of the Qu'Appelle River that lies over 1,800 feet in elevation, the low point being at the crossing of Lanigan Creek near the middle of this stretch. Between 320 and 390 miles from Wolf Lake Junction there is another area of internal drainage, into the Quill Lakes. Most of this stretch is below 1,800 feet in elevation, the low point being near the easternmost of the Quill Lakes. The remainder of the corridor in Saskatchewan lies in the drainage basin of the Assiniboine River, a tributary to the Red River. Most of the corridor lies below 1,800 feet in elevation, reaching as high as 1,800 feet near the beginning of this segment, and reaching low points at the crossings of the Whitesand River and two of its tributaries.

Most of the corridor in Manitoba, to about 645 miles from the beginning of the corridor, remains in the drainage basin of the Assiniboine River. It crosses the Assiniboine River twice, once just east of the Saskatchewan-Manitoba border, probably near 1,500 feet in elevation, and again near the end of this segment where the river level has dropped to about 1,000 feet above sea level. Most of the terrain in this part of the basin lies between 1,200 feet and 1,500 feet in elevation. A short distance east of the more easterly crossing of the Assiniboine River, the corridor passes into the drainage basin of the Red River itself, crossing several minor tributaries. The elevation rises to about 1,500 feet, and then drops to about 1,000 feet over a short distance while crossing the Manitoba Escarpment. From here to the U.S. border, the elevation gradually drops to below 800 feet at the crossing of the Red River at the end of the corridor in Canada.

Wolf Lake-Crowsnest Corridor

This corridor crosses terrain that rises in elevation from less than 1,800 feet at the beginning to over 5,000 feet at the end. It begins in the drainage basin of the Beaver River, but after 40 miles passes to the North Saskatchewan drainage, and then to the basins of several rivers that unite to form the South Saskatchewan River. The entire corridor lies within the Hudson Bay drainage system. For the first 40 miles the elevation is just over 2,000 feet, except near the crossing of Beaver River, about 20 miles down the corridor, where the elevation is somewhat below 2,000 feet. For the next 90 miles, in the drainage basin of the North Saskatchewan River, the elevations are all over 2,000 feet except at the North Saskatchewan

River crossing where the elevation is just below 2,000 feet. The Battle River drainage extends for the next 50 miles and elevations range from about 2,400 feet at the Battle River crossing to about 2,800 feet near the end of this stretch. Red Deer River drainage extends to about 275 miles from the beginning of the corridor, and the elevations range from a low of about 2,600 feet at the Red Deer River crossing to just over 3,000 feet at the end of the basin. For the next 30 miles or so the corridor crosses the drainage of the Bow River, crossing the river itself at an elevation of about 3,000 feet. Elevations generally are in excess of 3,000 feet.

The remainder of the corridor is in the drainage basin of the Oldman River. Low points are at the crossings of the Little Bow River, about 3,600 feet, Willow Creek, about 3,800 feet, and the Oldman River itself, just under 4,000 feet above sea level. Elevations rise above 4,000 feet crossing the Porcupine Hills and climb to over 5,000 feet at the end of the corridor at Crowsnest Pass, where the corridor joins the Kingsgate Delivery Line.

Dome and Brandon Corridors

The drainage basin that controls most of the streams in the region crossed by these corridors is that of the Assiniboine River. Only about 150 miles of the beginning of the Moose Jaw segment is in another drainage basin, that of the South Saskatchewan River. Both streams eventually join and enter Hudson Bay. A few areas crossed by these corridors have internal drainage. Most slopes along the corridors are nearly flat to very gentle. Only very locally are steep slopes encountered; most of these are at crossings of moderate and major streams. Relief along the corridors is probably no more than about 50 to 100 feet except near crossings of Swiftcurrent Creek and the Assiniboine River where relief is as much as 100 to 200 feet.

A general decrease occurs in altitude of the land from west to east. In western Saskatchewan much of the area crossed by the corridors is about 2,200 to 2,400 feet in altitude and in eastern Saskatchewan and southwestern Manitoba altitudes are about 1,700 to 2,000 feet. The area of highest altitude is about 2,500 feet and is found in an area near the beginning of the Moose Jaw segment between 10 and 20 miles east of the border between Alberta and Saskatchewan. The lowest altitude is 1,300 feet; it occurs at the crossing of the Assiniboine River about 55 miles west of the eastern end of the Brandon segment.

Geology

A generalized account of the principal elements of the geology along the Southern Canada Corridors is here given. Elements include physiography, bedrock geology, surficial deposits, mineral resources, seismicity, erosion and slope stability, and permafrost.

Physiography

All of the Southern Canada Corridors lie within the Interior Plains Region of Canada, except for the southwestern part of the Wolf Lake-Crowsnest Corridor which is within the Cordilleran Region.

Liard River-Wolf Lake Corridor--This corridor begins in the southwestern part of the Great Slave Plain, mostly crosses subprovinces of the complex Alberta Plateau physiographic province, and ends in the northern part of the Eastern Alberta Plains.

The first 65 miles of this corridor lies in the Great Slave Plain. This physiographic province has generally low relief, with the terrain sloping gently toward the west following the west-flowing Mackenzie River. In the part traversed by the corridor, however, the land generally rises southward toward the edge of the Alberta Plateau.

Most of the corridor lies in the Alberta Plateau, crossing in turn the following subprovinces: Cameron Hills Upland, the Fort Nelson Lowland, the Peace River-Wabasca Lowland (interrupted for a short distance by the Buffalo Head Hills Upland), the Birch Mountains Upland, the Algar Plain, and the Stony Mountain Upland. The upland parts of the plateau are part of a generally smooth surface that slopes gently northeastward from elevations of over 4,000 feet near the Rocky Mountains in the west, to about 2,500 feet in the northeast where the plateaus overlook the lower Great Slave, Saskatchewan, and Alberta Plains. The corridor generally traverses the northeastern part of the Alberta Plateau. The uplands are separated by lowland areas which generally are 1,000 feet lower than the uplands and follow the major rivers which were responsible for cutting them out of the upland surface.

The corridor first crosses the Cameron Hills Upland subprovince. This upland consists of a series of hills that rise several hundreds of feet above intervening lower areas.

The corridor then drops as much as 800 feet in elevation down onto the Fort Nelson Lowland, here drained to the northeast by the Hay River. The lowland has a very smooth, poorly drained, surface that slopes imperceptibly northeastward. At about 400 miles from its beginning the corridor passes from the Fort Nelson Lowland into the Peace River-Wabasca Lowland with little change in elevation. The Peace River and its major tributaries, in this area chiefly the Wabasca River, are incised below the generally flat surface of the lowland by several hundred feet, and the bluffs along these rivers form the major barriers in crossing the Alberta Plateau. For about 10 miles the corridor passes onto the edge of the Buffalo Head Hills upland, probably traversing an area of greater relief, but one that is also better drained.

The corridor continues up the valley of the Wabasca River and crosses the Birch Mountains Upland; thus it lies in the lowest part of the upland. The Wabasca valley has many of the smooth-surfaced, low-elevation characteristics of the adjacent lowlands. Here, however, the surface probably is better drained than in the lowlands proper.

Beginning at about 480 miles from the beginning of the corridor it passes into the Algar Plain which comprises both the divide between the Wabasca and Athabasca Rivers, and, in its eastern part, the valley of the Athabasca River. It is a relatively high-lying plain, partly dissected; in the central part of the plain the drainage is poorly organized and internal. The corridor then enters the smooth-surfaced to gently rolling Stony Mountain Upland, the easternmost part of the Alberta Plateau.

For the last 40 miles the corridor drops down onto the northernmost part of the Eastern Alberta Plains, although for part of this distance it is at the edge of the adjacent Mostoos Hills Upland, and thus traverses terrain that undulates between more rolling uplands and more typically smooth plains surfaces; in part this transition zone may be somewhat dissected.

Wolf Lake-Emerson Corridor--This corridor traverses in turn the following subprovinces: northeastern part of the Eastern Alberta Plains, the Saskatchewan Plains and the Manitoba Plains. Each plain lies to the east or northeast of and is lower in elevation than the preceding plains and is generally separated from adjacent plains by an escarpment.

For the first 10 miles the corridor continues along the edge of the Mostoos Hills Upland, and then passes across the Beaver River Valley, which is cut somewhat below the general elevation of the Eastern Alberta Plains. The surface of this valley is gently undulating.

The corridor then crosses the Thickwood Hills Upland, part of the relatively high, gently to strongly rolling northeastern edge of the Eastern Alberta Plains. At the end of this long and relatively narrow subprovince, the corridor descends to the lower Saskatchewan Plains.

The corridor crosses the Saskatchewan Plains between 215 and 670 miles from its beginning. There are several subprovinces, including in turn the Saskatchewan Rivers Plain, the Lake Lenore Upland, the Quill Lakes Plain, the Assiniboine River Plain, and the Pembina Hills Section of the Manitoba Escarpment.

The Saskatchewan Rivers Plain is the flat floor of a former glacial lake. The North Saskatchewan and the South Saskatchewan Rivers are incised a few hundred feet beneath the plain, and are bordered by steep bluffs. There are also a few other interruptions to the generally flat terrain where the corridor crosses a generally hummocky area of sand dunes, and an area of gently to strongly rolling terrain, the Minichinas Hills. The corridor then crosses the gently to strongly rolling area of the Lake Lenore Upland that rises above the general elevation of the surrounding plains.

For about the next hundred miles the corridor lies in the Quill Lakes Plain, a gently undulating region with relatively low slopes. Most of this plain occupies the area of internal drainage into the Quill Lakes.

From this plain the corridor passes to the Assiniboine River Plain, which continues the same general pattern of gently undulating terrain, at slightly lower elevations than the preceding Quill Lakes Plain. The Assiniboine River, however, is incised beneath the general level by 100 to 200 feet and in places is bounded by steep slopes. At the southeastern end of the Saskatchewan Plain the corridor passes over the Pembina Hills section of the Manitoba Escarpment for about 20 miles. The Manitoba Escarpment extends interruptedly along the northeastern margin of the Saskatchewan Plain and where crossed by the corridor the escarpment is about 500 feet high.

The last 60 miles of the corridor crosses the flat to very gently undulating plain of the Lake Agassiz Plain sector of the Manitoba Plains.

Wolf Lake-Crowsnest Corridor--This corridor begins at the northern end of the Eastern Alberta Plains, which it crosses for more than half of its route. It then passes diagonally across the Western Alberta Plains and the Porcupine Hills before entering the Cordilleran Region. The corridor then crosses the Rocky Mountain Foothills and ends in the Rocky Mountains Physiographic Province near the Continental Divide.

The Eastern Alberta Plains is a large physiographic province that occupies much of eastern Alberta and western Saskatchewan. It comprises smooth-surfaced terrain that slopes gently eastward from the higher plains to the west, ending in an escarpment overlooking the lower plains to the east. The major rivers are incised as much as 400 feet below the general surface. In crossing this physiographic province for the first 215 miles of its route the Wolf Lake-Crowsnest Corridor climbs from the lower eastern side of the plains to the higher western side, but at an angle to the general slopes, so that the corridor does not rise as rapidly in elevation as if the plains were traversed directly upslope.

The Western Alberta Plains are crossed between 215 and 325 miles from the beginning of the corridor. These plains are higher in elevation and somewhat more irregular on their surface than are the eastern plains but they generally have the nearly flat surface characteristic of plains in general. They also slope gently to the east from the Rocky Mountain Foothills.

The corridor then crosses the Porcupine Hills for about 25 miles. These hills represent the highest, westernmost part of the Western Alberta Plains, in an area above 4,000 feet in elevation where there is greater relief and more dissection.

For the next 30 miles the corridor crosses the linear ridges of the Rocky Mountain Foothills. These hills have relief of up to 1,000 feet and reach elevations of 5,000 to 7,000 feet above sea level.

For the last 5 miles of its route the corridor is within the the Rocky Mountains. The corridor ends Crowsnest Pass, a low point on the Continental Divide.

Dome and Brandon Corridors--From west to east three physiographic provinces of the Interior Plains are crossed. These are the Eastern Alberta Plains, the Saskatchewan Plains, and the Manitoba Plains. Uniform-sloping, east-facing escarpments several hundreds of feet high form the boundaries between these three subprovinces. The westerly escarpment, called the Missouri Coteau, is crossed about 15 miles west of the city of Moose Jaw; the scarp divides the Eastern Alberta Plain from the Saskatchewan Plains. The easterly scarp is the Manitoba Escarpment which is located about 50 miles northwest of Emerson, Manitoba.

Bedrock

The bedrock underlying the Southern Canada Corridors consists entirely of bedded sedimentary rocks of Paleozoic and Mesozoic ages. Most of these rocks are shale with some interbedded sandstone and minor amounts of low-rank coal. Some of the shale has a high percentage of bentonite. The shale is generally soft, has a relatively low bearing capacity, and is easily eroded. Bentonite, because of its potential for swelling in many places, has caused damage to engineering structures. Along the southwesternmost part of the Wolf Lake-Crowsnest Corridor in the Rocky Mountains there are large areas of coarser-grained rocks generally of higher strength, such as sandstone, conglomerate, and quartzite; carbonate rocks are a minor constituent. The structure of most of the rocks is simple; beds are flat lying and thus indicate little disturbance since deposition and lithification. In the Rocky Mountains, however, geologic structure is more complex, as indicated by folding and faulting of beds. Most bedrock is concealed beneath glacial deposits; exposures are chiefly along the moderately steep to very steep slopes of valleys cut by major glacial and postglacial streams.

Material in this section was derived mainly from the geological map of Canada (Canada Geol. Survey, 1969), the Atlas of Alberta (Govt. of Alberta, 1969), and the Atlas of Saskatchewan (Richards and Fung, 1969).

Liard River-Wolf Lake Corridors--The first twenty miles of this corridor crosses relatively flat-lying Devonian shale and siltstone. Next, are flat-lying Lower Cretaceous calcareous shale containing some bentonite beds; shale continues south to a point slightly south of the Peace River. The remainder of the corridor is underlain by Lea Park bentonitic shale of Upper Cretaceous age.

Wolf Lake-Emerson Corridor--For about 585 miles this corridor crosses flat-lying Upper Cretaceous gray to black shale with cream-colored lenses of bentonite. The route then traverses southwest-dipping bentonitic shale of Lower Cretaceous age and continues along the strike of the shale beds for about 85 miles. For the last 60 miles the corridor traverses southeast-dipping beds of Cretaceous and Jurassic shale, sandstone, limestone, and siltstone.

Wolf Lake-Crowsnest Corridor--For about the first 175 miles, the corridor traverses chiefly rocks of Upper Cretaceous age consisting of flat-lying shale with interbedded bentonite, sandstone, and coal. For about the nest 180 miles, as far as the Rocky Mountain foothills, the corridor passes over flat-lying Tertiary and Cretaceous sandstone with interbedded shale and coal. In the last 30 miles the corridor first crosses upturned Cretaceous shale and sandstone, and then passes over folded and faulted sandstone, limestone, and quartzite of Paleozoic age.

Dome and Brandon Corridors--Much of the length of these corridors is entirely underlain by flat-lying Upper Cretaceous Bear Paw Formation or equivalents. Bedrock generally is exposed only along the valley sides of entrenched streams. The Bear Paw Formation along the Moose Jaw segment is characterized by soft clay shale with minor sandstone and siltstone and occasional beds of bentonite and coal; along the Brandon segment, the formation is more commonly clay shale. The Dome segment crosses Bear Paw Formation for about the first 73 miles; the last 110 miles traverses interbedded shale and sandstone of Tertiary age.

Surficial Deposits

Several types of surficial deposits exist along the Southern Canada Corridors. Most deposits owe their origin to the Laurentide Ice Sheet of the last major glaciation. Many of these deposits have a high content of silt and clay. Some unglaciated or very old glaciated areas are present near the Rocky Mountains. Locally, postglacial organic deposits and some alluvial sand and gravel deposits, are present. Descriptions of surficial geologic materials along the corridors are based upon the grouping of similar deposits into linear segments that vary from several to many miles in length. Descriptions of deposits are generalized from data by: Charron (1961), Elson (1960), Government of Alberta (1969), Johnston and others (1948), Klassen (1966), Prest and others (1968), and Richards and Fung (1969).

Liard River-Wolf Lake Corridor--From the beginning of this corridor to about 45 miles south of the border between Northwest Territories and

Alberta, deposits are mostly glacial diamicton in moraines that vary from gently rolling to nearly smooth. There are some small glacial ice-contact and lacustrine deposits of sand, gravel, and silt as veneers as much as 5 feet thick over diamicton. This diamicton probably has a large percentage of silt and clay; where perennially frozen locally it may be ice-rich. Organic deposits are small but their occurrence is widespread; commonly, they are permanently frozen and locally they may be ice-rich. Organic deposits underlie 30 to 50 percent of this segment of the corridor. For the next 50 miles, including the Hay River crossing, chiefly glaciolacustrine deposits of silt and clay are present. Organic deposits are abundant locally; some of these probably are perennially frozen. In the succeeding 35 miles, which extends to 5 miles beyond the Peace River crossing, there is a complex of deposits that includes: (1) glacial diamicton with a large percent of silt and clay, (2) glacial lake deposits of silt and clay, and (3) glacial outwash composed of sand and gravel. There is some post-glacial alluvium near the Peace River crossing; locally sand dunes may be present. For the next 100 miles, the corridor lies mainly within the valley of the Wabasca River, and deposits consist predominantly of glaciolacustrine silt and clay. There are some variably stony glacial diamicton deposits. A few glacial and post-glacial alluvial deposits of sand and gravel occur near major streams.

In the remaining 265 miles of the corridor, deposits probably consist of a complex of (1) glaciolacustrine silt, clay, and sand, and (2) glaciofluvial sand and some gravel. Glacial diamicton underlies some parts of the corridor in stretches as much as 20 miles long. Organic deposits are extensive locally especially in the last 18 miles.

Wolf Lake-Emerson Corridor--From Wolf Lake Junction to about 130 miles beyond the border between Alberta and Saskatchewan, the corridor crosses predominantly gently rolling ground moraine composed of glacial diamicton having a large percentage of silt and clay. Organic and some lake deposits are extensive locally.

For the next 55 miles deposits consist chiefly of silt and clay related to glacial lakes. Near crossings of the North Saskatchewan and the South Saskatchewan Rivers, there are extensive deposits of glacial and post-glacial alluvial sand and probably gravel. Sand dunes occur near the North Saskatchewan River crossing.

The corridor then traverses about 60 miles of mostly hummocky moraines of variably stony diamicton. Glaciolacustrine deposits of silt and clay overlie the diamicton in places. For the next 45 miles, the corridor crosses chiefly gently rolling to smooth ground-moraine plains. Deposits are diamicton with a large percent of silt and clay; organic deposits probably are extensive locally. The corridor then traverses about 90 miles of mostly glacial lake deposits of silt, clay, and sand; deposits overlie fine-grained glacial diamicton at depths of probably less than 10 feet. In the last 50 miles in Saskatchewan, deposits consist predominantly of variably stony glacial diamicton in hummocky moraines. Veneers of sand and gravel probably cover some diamicton deposits; locally, organic deposits underlie extensive areas.

For the first 100 miles in Manitoba, the corridor crosses mostly hummocky to gently rolling moraines of variably stony glacial diamicton that have a large percentage of silt and clay; glacial ice-contact deposits of sand, gravel, and silt probably occur in some places. Organic deposits locally cover large areas. Some glacial and post-glacial alluvium consisting of sand, silt, and gravel is located near crossings of the Assiniboine River, Birdtail Creek, and the Minnedosa River.

In the next 50 miles deposits are chiefly sandy and silty lacustrine and deltaic deposits of glacial Lake Agassiz; locally, these sediments are interbedded with clay. Post-glacial alluvial deposits of sand, silt, and some clay occur near the second crossing of the Assiniboine River. Organic deposits are present locally. The corridor then traverses about 20 miles of gently rolling to hummocky moraine consisting of glacial diamicton with a large proportion of silt and clay; there are some ice-contact deposits composed of sand, gravel, and silt.

The remaining 64 miles of the corridor is underlain dominantly by silt and clay deposited in glacial Lake Agassiz; thin mantles of sand occur in some places. Thin organic deposits may be extensive locally. Post-glacial alluvial deposits of sand, silt, and gravel are present near the Red River.

Wolf Lake-Crowsnest Corridor--Deposits in the first 200 miles of this corridor consist mostly of variably stony glacial diamicton formed into gently rolling to hummocky moraines. Near major streams there is glacial and post-glacial alluvium of sand and gravel; a few glaciolacustrine deposits probably are present locally.

For the next 90 miles, including the Red Deer River crossing, the corridor traverses dominantly glaciolacustrine deposits of silt and clay. Some glacial diamicton occurs locally. In the next 40 miles from near the Bow River to the flanks of Porcupine Hills most deposits are stony glacial diamicton in rolling to smooth ground moraine; alluvial deposits are present locally. In the next 25 miles the corridor crosses the Porcupine Hills where there probably are some thin to very thin deposits of bedrock rubble mixed with silt and sand.

In the last 30 miles the corridor traverses a complex of variably thick deposits, most of which are probably glacial diamicton in rolling to hummocky moraines. There are many small deposits of (1) glaciolacustrine silt, clay, and sand, (2) glacial and post-glacial alluvial gravel and sand, and (3) colluvium.

Dome and Brandon Corridors--The first about 65 miles of the Moose Jaw segment traverses several types of deposits, including (1) large areas of rolling to hummocky ground moraine of glacial diamicton, (2) a sector of sand dunes extending about 15 miles along the route, and (3) some glacial lacustrine deposits. The next 50 miles traverse chiefly glacial lacustrine deposits, probably silt and clay. The crossing of Swiftcurrent Creek is entrenched as much as 100 feet below the general level of the lake deposits; slopes down to the creek possibly show some landslides. The next 55 miles largely is hummocky to very hummocky moraines of glacial diamicton. Locally, deposits of sand dunes, glacial and postglacial lake sediments, and probably some organic deposits are prominent. The final 48 miles of the Moose Jaw segment and the first 35 miles of the Brandon segment cross glacial lacustrine deposits of probably silt and clay; some alluvial sand and gravel deposits are present near streams in the vicinity of Moose Jaw and Regina. The next 142 miles of the Brandon segment crosses rolling to very hummocky moraines of probably medium grained glacial diamicton. Within the moraine area are some ice-contact deposits of sand and gravel and many areas with numerous small ponds and organic deposits. Glacial outwash deposits of sand and probably some gravel are evident locally. The last 56 miles of the corridor are marked by several types of surficial deposits. Of this distance, the first 5 miles are marked by the crossing of the Assiniboine River with its (1) steep, possibly landslide-prone valley walls with bedrock exposed, locally, and (2) glacial and postglacial alluvial deposits of probably gravel and sand. The remainder of the segment crosses rolling to hummocky moraines of fine to medium glacial diamicton with many small ponds and probably organic deposits, especially between the Assiniboine and Minnedosa Rivers. Some glacial and postglacial alluvial gravel and sand deposits probably are present near the crossing of the Minnedosa River.

The Dome segment in its first 80 miles crosses glacial lacustrine deposits mostly of silt and clay. The next 90 miles of the segment traverses smooth-to rolling-to hummocky moraines of probably fine-grained glacial diamicton. Within the area of moraine there probably are some ponds and probably some organic deposits and ice-contact deposits of sand and gravel. Glacial and postglacial alluvial deposits of sand and gravel may be present near the end of this segment near the Souris River. The final 13 miles of the Dome segment crosses glacial lacustrine deposits probably of silt and clay.

Mineral Resources

Several developed and presently undeveloped mineral deposits and coal and gas resources are present along the Southern Canada Corridors.

Metallic and Nonmetallic Mineral Deposits--In the area near the Liard River-Wolf Lake Corridor no metallic or non-metallic mineral deposits are sufficiently developed and large enough (36,000 tons historic production) to appear on the map "Mineral Deposits of Canada" (Douglas, 1970, map 1252 A).

The Wolf Lake-Emerson, Wolf Lake-Crowsnest, Dome and Brandon Corridors cross at depth parts of the Prairie evaporite basin of Devonian age. From this basin potash is mined near Saskatoon, Saskatchewan, and in southeastern Saskatchewan; it probably underlies most of the intervening area (Little and others, 1970, p. 519-520). In addition, sodium sulphate and salt are mined in several places in southern and western Saskatchewan and in eastcentral Alberta (Douglas, 1970, map 1252 A). Brine from the salt deposit at Duvervay, Alberta is used to make caustic soda, chlorine, and hydrochloric acid (Little and others, 1970, p. 519). In that part of the evaporite basin in Manitoba there is a gypsum deposit with combined production and reserves of less than 1 million tons and a salt deposit with combined production and reserves in excess of 15 million tons (Douglas, 1970, map 1252 A).

Along most of the corridors, geologic materials for construction purposes probably are quite readily available; locally, however, material may be scarce.

Coal--Most of the area traversed by the Southern Canada Corridors between the Athabasca River in Alberta and the central and southern parts of Saskatchewan is underlain by subbituminous coal and lignite of Upper Cretaceous and Paleocene age. There are, however, no major mines near the corridors except near the southeastern end of the Dome segment and at Drumheller, northeast of Calgary (about 20 miles east of the Wolf Lake-Crowsnest Corridor) (Little and others, 1970, p. 524; fig. IX-14). Coal near the end of the Wolf Lake-Crowsnest Corridor is discussed in Section 2.1.2.3.

Oil and Gas--Considering oil and gas resources, a 300-mile-wide zone along the Wolf Lake Corridors has its western part overlapping the eastern limit of the maturely explored and developed British Columbia-Alberta oil and gas province. the eastern part of the 300-mile-wide zone overlaps the extension of the Albertan oil and gas province into westernmost Saskatchewan and overlaps the Williston sedimentary rock province of southern Saskatchewan and southwestern Manitoba. The zone also covers most of the Athabasca and other oil-sand deposits of Alberta.

Gas reserves and potentials of the British Columbia-Alberta oil and gas province have been described in Section 2.1.2.3. In the Williston basin proper, gas has been produced along with oil from thick sections of rock. Recent exploration in the Williston basin for gas, alone, has been successful and the reserves of 1.5 tcf, estimated by McCrossan and Porter (1973, p. 649), are thought to be slightly more than one-half the potential that ultimately will be recovered from the basin.

Seismicity

The earthquake history along the Southern Canada Corridors is short relative to the time over which strains accumulate to produce an earthquake, hence the historic record of seismicity is a limited guide to future seismic risk. Earthquakes of magnitude 6 and larger are potentially destructive, and earthquakes of magnitude 5 may even cause local damage. North of 60° N. latitude, the seismic history is probably complete since the early 1930's for earthquakes as small as magnitude 6 and since the late 1950's or early 1960's for shocks as small as 5 (Stevens and Milne, 1973; Leblanc and Wetmiller, 1974). The historic record is somewhat better for Alberta, Saskatchewan, and Manitoba.

The historic record indicates that the level of earthquake activity along the Southern Canada Corridors is very low. The earthquake potential along the corridors may be specified in terms of a maximum expectable earthquake of magnitude 4.5 except along parts of the Dome and Brandon Corridors and along the southwest end of the Wolf Lake-Crowsnest Corridor south of 50° N. latitude where a maximum expectable earthquake of magnitude 5.5 is appropriate. The maximum expectable earthquake is the largest earthquake that on the basis of existing knowledge may reasonably be expected to occur; it exceeds the largest known historic earthquake. The zonation of the corridors might be refined if more complete geologic and geophysical data were available.

Erosion and Slope Stability

The natural removal or movement of geologic materials from sites of deposition is accomplished by several agencies including: (1) freezing and thawing, (2) running water, and (3) downslope mass movement like landslides. The level of activity chiefly depends upon (1) the type of geologic material itself, (2) climate and specific meteorological conditions, and (3) the slope angle or inclination of the land surface.

The predominant type of bedrock along the Southern Canada Corridors is soft shale (some with bentonite) interbedded with varying amounts of sandstone. Most surficial deposits are variably stony glacial diamicton having a large percentage of silt and clay, although of almost equal importance are glacial lake deposits of silt and clay.

Along the Southern Canada Corridors climatic and specific meterological conditions of prime concern to slope stability and erosion are: (1) the total amount of precipitation, (2) the intensity of rainfall, and (3) the rapidity of snowmelt. At times, any one or several of these factors may combine to cause a large increase in the susceptibility of: (1) slopes to failure, or (2) sheet wash and streams to remove large quantities of geologic materials.

Along the greater part of the corridors, slopes range from gentle to nearly flat. Only where the corridors cross major rivers are slopes steep to very steep. Many of the slopes at major river crossings are underlain by weathered shale (some with bentonite) or by lake deposits or diamicton deposits with a large percentage of silt and clay. All of these geologic materials are susceptible to failure.

A report by Kathol and McPherson (1974) that discusses problems of erosion and slope stability encountered while developing oil fields in an area of geological conditions similar to those found along part of the Liard River-Wolf Lake Corridor is an instructive account of some of the problems that might develop during construction and operation of the proposed pipeline if appropriate preventive measures are not taken. It points out the great ease with which very soft rocks erode and move by mass wastage when cut and excavated for roads and other facilities. The report also indicates the difficulty of achieving revegetation in attempts to reestablish stable conditions of slopes.

Permafrost

Of the Southern Canada Corridors, only the three Wolf Lake Corridors probably have scattered, isolated patches of permafrost. Permafrost would not be a major factor in construction along any of these Wolf Lake Corridors except possibly along the northwestern part of the Liard River-Wolf Lake Corridor. However, occurrences of permafrost are not readily predictable and the uncertainty of location of these occurrences might be as much of a problem as the necessary treatment of the permafrost problem itself. Most of the permafrost patches that might be encountered are likely to be at temperatures not far below freezing, and are thus readily susceptible to thawing. They are also likely to be relatively thin so that thawing may not induce large-scale subsidence effects; however, effects detrimental to the integrity of a pipeline cannot be ruled out, and it is even possible that some permafrost occurrences are at such depths that they would not be encountered during construction and that the effects of thawing would not become apparent until after a pipeline was in use.

Liard River-Wolf Lake Corridor--This corridor begins in the southern fringe of the discontinuous zone of permafrost and continues in the zone for about 390 miles of its route, to a point in the valley of the Wabasca River. In this zone fairly extensive areas of permafrost can be expected to be present.

Beyond about 390 miles from its beginning, the corridor traverses land that is thought to be generally free of permafrost. Even as far south as Wolf Lake Junction and beyond, however, isolated patches of permafrost have been found, although no such occurrences have been reported in the actual vicinity of the corridor probably because of the largely undeveloped state of the country.

Wolf Lake-Emerson Corridor--Almost all of this corridor lies in the area generally considered to be free of permafrost. Only the northwestern 30 to 50 miles of the corridor passes close to or through the edge of an area known to have permafrost (Brown 1967). Southeast of this area there are no known permafrost occurrences, and it is considered unlikely that there would be any beyond about 100 miles from the beginning.

Wolf Lake-Crowsnest Corridor--This corridor lies entirely in the area generally considered free of permafrost. There are no known occurrences of permafrost, even at the north end of the corridor, but, as far south as the North Saskatchewan River, small occurrences might be found. South of the North Saskatchewan River there is unlikely to be any permafrost.

The last 40 miles of the corridor passes through mountainous areas, where there may be permafrost at elevations over about 5,500 feet. A pipeline built in the corridor probably would not reach elevations this high, but should a route be chosen that would climb to such elevations, isolated patches of permafrost, particularly on shaded, north-facing slopes, might be encountered.

Dome and Brandon Corridors--These corridors lie entirely in areas free of permafrost.

Soils

The Southern Canada Corridors cross several different types of soils between the Northwest Territories and the United States border. The Liard River-Wolf Lake Corridor is the farthest north and would traverse Gelic and Dystric Histosols and some Luvisols; boglands are widespread, although some of the area is classified as pasture and woodland.

The Wolf Lake-Emerson Corridor would cross approximately equal areas of Chernozems and Luvisols of the Aspen Parkland natural-vegetation region.

The Wolf Lake-Crowsnest Corridor would encounter mostly Chernozems with some Luvisols and Solonetz soils. The Chernozems occur on natural grasslands and parklands of the prairie region.

The Dome and Brandon Corridors would cross soils that are predominantly Chernozems of natural grasslands.

Water Resources

Surface Water

Most of the Southern Canada Corridors are in the Interior Plains Physiographic Region. Streamflow statistics and information from selected stream-gaging stations are given in Table 8.1.2.7-1. Additional data are available in publications of the Water Survey of Canada. Although the actual number of streams is not known, an estimate of stream density is that the pipeline will cross about 474 minor and 50 major stream channels along the Wolf Lake Corridors, and about 69 minor and 9 major stream channels along the Dome and Brandon Corridors (Table 8.1.2.9-16).

In much of the area crossed by all of the Southern Canada Corridors except the Wolf Lake-Crowsnest Corridor, runoff is less than one inch. Winter flows are very low in comparison to the mean annual flow for major streams. Many of the streams with smaller drainage areas have no flow during the winter. Flood flows can be many times greater than the mean annual flow, as shown in Table 8.1.2.7-1.

Runoff is greater in streams with headwaters in the Rocky Mountain Foothills and the Rocky Mountains. These streams generally have flow during the winter. Representative minimum flow values and flood magnitudes for the

Table 8.1.2.7-1 Summary of selected streamflow records along the Wolf Lake Corridors

Station no.	Name	Drainage area (sq.mi.)	Location	Discharge records	Type of gage	Operation	Mean (cfs) (in)	Max. daily (cfs)	Min. daily (cfs)	Remarks
	HAY RIVER/MACKENZIE RIVER:									
07OC001	Chinchaga R nr High Level, Alb.	4,160	58°35'48" 118°20'00"	69-	R	C	1,360 4.42	b27,200 5-7-72	0.1 2-21-71	
07OB001	Hay R nr Hay River, N.W.T.	18,500	60°44'45" 115°51'20"	29-31 63-	M R	S C	2,950 2.17	b36,000 5-10-67	10 2-11-71	
	PEACE RIVER/MACKENZIE RIVER:									
07HF001	Peace R at Fort Vermilion, Alb.	86,000	58°23'15" 116°02'05"	15-22,60-61 62 63-66 67-	M M R R	S C C S	106,000 -	437,000 6-16-64	19,700 10-23-68	Regulated since 1968.
07JF002	Boyer R nr Fort Vermilion, Alb.	2,420	58°26'42" 116°16'10"	62-68 69-	M R	S S	(c)	4,120 5-3-63	0 Many days	
07JF003	Ponton R ab Boyer R, Alb.	984	58°27'53" 116°15'23"	62-	M	S	(c)	b5,850 5-23-67	0 Many days	
	ATHABASCA RIVER/MACKENZIE RIVER:									
07BE001	Athabasca R at Athabasca, Alb.	29,600	54°43'20" 113°17'10"	12-31,51-58 38-50 59-	M M R	C S C	15,200 6.97	b200,000 6-10-54	1,490 1-18-53	
	CHURCHILL RIVER:									
06AD006	Beaver R at Cold Lake Reserve, Alb.	5,460	54°21'20" 110°13'00"	55-59 70-	M R	C C	945 2.35	b21,800 6-13-62	13.0 2-14-64	

continued on next page

Table 8.1.2.7-1 Continued

Station no.	Name	Drainage area (sq.mi.)	Location	Discharge records	Type of gage	Oper- ation	Mean (cfs) (in)	Max. daily (cfs)	Min. daily (cfs)	Remarks
	SASKATCHEWAN RIVER/NELSON RIVER:									
05AA008	Crowsnest R at Frank, Alb.	162	49°35'49" 114°24'33"	10 11-20 49-63 64-	M M R R	S C S C	187 15.7	b2,610 6-9-53	21.0 3-29-17	
05AA023	Oldman R nr Waldron's Corner, Alb.	551	49°48'50" 114°11'00"	49-	R	C	494 12.18	b16,000 6-8-53	37 11-21-70	
05CE002	Kneehills C nr Drumheller, Alb.	950	51°29'28" 112°50'41"	21-31,35-36 57-58 59-	M R	S S	f34 0.5	b4,710 4-9-71	No flow Many days	
05CE005	Rosebud R at Redland, Alb.	1,400	51°17'35" 113°00'10"	51-	M	S	f60 0.6	6,240 4-9-71	No flow 3-1-70	
05HG001	S Saskatchewan R at Saskatoon, Sask.	53,900	52°08'26" 105°48'20"	11-62 69-	M R	C C	9,680 1.97	b148,000 7-7-69	502 2-2-63	Regulated
05FC001	Battle R nr Forestburg, Alb.	3,020	52°34'23" 112°20'48"	66 67-	R R	C S	(c)	b1,740 5-1-71	No flow Many days	Seasonal average March-October, about 163 cfs.
05GF001	Shell Brook nr Shellbrook, Sask.	1,360	53°15'00" 106°23'00"	64 65-	M R	S S	(c)	b903 4-21-72	0 Many days	
05GG001	N Saskatchewan R at Prince Albert	46,300	53°12'10" 106°46'06"	10-64 65-	M R	C C	8,614 2.53	b200,000 6-2-15	395 1-23-35	Regulated since 1962.

continued on next page

Table 8.1.2.7-1 Continued

Station no.	Name	Drainage area (sq.mi.)	Location	Discharge records	Type of gage	Oper-ation	Mean (cfs) (in)	Max. daily (cfs)	Min. daily (cfs)	Remarks
	ASSINIBOINE RIVER/NELSON RIVER:									
05MA012	Ironspring C nr Watson, Sask.	177	52°06'53" 104°32'21"	26,60-62, 63-65 66-	M R	S S	(c)	b552 4-22-72	0 Many days	Regulated.
05MB004	Whitesand R nr Sheho, Sask.	426	51°35'34" 103°02'38"	57, 73- 58-72	M R	S S	7.15 0.23	366 4-18-66	0 Many days	Regulated.
05MB001	Yorkton C nr Ebenezer, Sask.	949	51°22'50" 102°30'11"	41-70 71-	M R	S S	(c)	1,920 4-12-60	0 Many days	Regulated.
05ME001	Assiniboine R nr Russell, Mant.	7,640	50°48'35" 101°26'10"	13-32,50-57, 67-68 42-49 58-66, 69-	M M R	C S C	(c)	(c)	(c)	Regulated since 1969.
05MH005	Assiniboine R nr Holland, Mant.	61,300	49°41'54" 98°53'56"	54-66 67-	M R	S C	(c)	(c)	(c)	Regulated.
05OC001	Red R at Emerson, Mant.	40,200	49°00'30" 97°12'40"	12-52, 64 53-63, 65-	M R	C C	(c)	(c)	(c)	Regulated.

continued on next page

Table 8.1.2.7-1 Continued

M	Manual gage.	a	Estimated.	e	Minimum monthly mean discharge
R	Recording gage.	b	Maximum instantaneous discharge.	f	From "Hydraulic and Geomorphic Characteristics of Rivers in Alberta."
C	Continuous operation.	c	Insufficient data.		
S	Seasonal operation.	d	Maximum monthly mean discharge.		

NOTE: The number of years used to compute or estimate the mean discharge does not necessarily correspond to the full period of continuous gage operation shown. Means for seasonal records were estimated in a few cases. These estimates should be reasonably reliable, since winter flows were generally low.

The maximum daily discharges are shown for most stations because that was all that was published. Instantaneous discharges are shown when they are available. The maximum daily discharge may be considerably smaller than the instantaneous peak for small and intermediate streams. Maximum stages are not shown, but they may or may not have occurred at the time of maximum discharge. The highest stage might occur as the result of an ice jam.

Caution should be used in interpreting minimum-flow figures. They are the lowest values published, but lower values may have occurred during periods of seasonal observations.

Cordilleran Region are shown in Table 8.1.2.7-1 for the Oldman and Crowsnest Rivers along the Wolf Lake-Crowsnest Corridor.

Surface waters in the Southern Canada Corridors vary in degree of mineralization and hardness.

Streams originating in the Cordilleran Region contain medium-hard water of the bicarbonate type. Many of these streams flow through the Interior Plains Region, where the hardness and sulfate content increase. Mineral content is highest in the Saskatchewan River basin. Many river waters in this basin are comparatively hard, have a high concentration of alkalis and sulfates, and require treatment before use (Thomas, 1964).

The Wolf Lake-Emerson Corridor and part of the Dome and Brandon Corridors traverse the Assiniboine River drainage. The rivers crossed by these corridors rise in the Saskatchewan Plain or Manitoba Plain. The water in this area is highly mineralized and turbid. Concentrations of sodium and sulfate are much higher than in waters of the Canadian Shield or Cordilleran Regions (Thomas, 1964). Only the larger rivers can be used by industry and even these are of poor quality, requiring extensive treatment before use. Thomas (1964) reports a water-quality analysis for the Assiniboine River at Headingly, Manitoba, (near Winnipeg, collected in November 1953, with a dissolved-solids concentration of 587 mg/l. The water had a hardness of 379 mg/l and contained 182 mg/l of sulfate.

During the winter months when streams are frozen and the terrain is snow covered, suspended-sediment concentrations are low, generally less than 70 mg/l (Stichling, 1974). Suspended-sediment concentrations during the open-water season are quite variable. Highest concentrations occur during the spring breakup and summer-storm events. Maximum suspended-sediment concentrations in excess of 10,000 mg/l are reported for the Red Deer River, a tributary of South Saskatchewan River (Water Survey of Canada, 1969a,b).

Ground Water

The Southern Canada Corridors pass through three hydrogeologic regions: the Northern, the Interior Plains, and the Cordilleran. Most of the area has been glaciated. Surficial deposits include glacial drift and alluvial deposits and range from fine lacustrine and till deposits to coarse glacial outwash and alluvial deposits.

North of 58° N. latitude the corridors are in the southern fringe of the discontinuous permafrost zone. In the discontinuous permafrost, villages have developed their ground-water resources in unfrozen alluvial aquifers adjacent to the rivers. In the Interior Plains the ground-water resources are highly developed. Low-yield domestic wells penetrate the till deposits; municipal and industrial wells pump water from the sedimentary bedrock units (Meyboom, 1967). Ground water in the Cordilleran Region is pumped from alluvium and glacial-drift deposits.

Water quality along Southern Canada Corridors ranges from a calcium or magnesium bicarbonate type with moderate concentrations of dissolved solids to a calcium or magnesium sulfate type with high dissolved-solids concentrations.

Vegetation

Description of the vegetation of the Southern Canada Corridors is based primarily upon CAGPL (1974e); Fremlin (1974); Government of Alberta (1969); Richards and Fung (1969); Rowe (1972); and Weir (1960).

Liard River-Wolf Lake Corridor

This alternative corridor (Figures 8.1.2-1 and 2) lies entirely within the Boreal Forest Formation (Figures 8.1.2.1-2 and 8.1.2.4-6). From its point of departure from the proposed route (Figure 8.1.2.7-1) in the Great Slave Plain, the corridor lies in the Upper Mackenzie Section of the Boreal Forest (Rowe, 1972). At about the latitude of the Kakisa River (Figure 8.1.2.7-1), it enters the Hay River Section which extends southward to about Fort Vermilion. From the latter point to its terminus at Wolf Lake Junction, it lies within the Mixedwood Section.

The corridor rather closely parallels the proposed route through the Hay River Section and the vegetation is the same as described previously (Section 2.1.2.6).

The general trend of vegetation from the point of origin of the corridor is from forest dominated by white spruce, jack pine and balsam poplar, as far as the Kakisa River (Figure 8.1.2.4-6); to dominance of black and white spruce and aspen from the Kakisa River to Fort Vermilion; and to an increase in dominance of aspen, relative to white and black spruce, through the remainder of the corridor, in the Mixedwood Section.

For the first 80 miles, in the Upper Mackenzie Section, white spruce and balsam poplar are dominant on alluvial flats and on the benches above flood plains. Adjacent upland areas of sandy soils have forests of jack pine and trembling aspen. Black spruce and tamarack occupy the moist to wet sites.

For approximately the next 190 miles, black spruce covers a large part of the land, forming stands on both uplands and lowlands. Forests of white spruce mixed with trembling aspen are less abundant and of lesser quality than farther south.

About 50 percent of the area traversed is productive or potentially productive forest land, primarily of deciduous forest species and mixedwoods. White spruce of excellent merchantable quality occurs along the lower Peace River flood plains to the east of the corridor. Grassland areas are crossed at the Hay River and Aspen Parkland along the Peace River, in the region about Fort Vermilion. The latter is largely converted to cropland and pastures. Muskeg with scattered black spruce and sphagnum moss groundcover occurs intermittently throughout this segment.

The remaining 348 miles of the 618-mile-long corridor lies within the Mixedwood Section. The forests of the uplands are variable mixtures of aspen, balsam poplar, white birch, white spruce, and balsam fir. Jack pine is dominant on sandy soils, occurs with black spruce on plateau-like hilltops, and is mixed with other species on drier glacial tills. Jack pine is a more important forest constituent south and east of the Athabasca River. Muskeg with black spruce is common throughout this segment of the corridor and greatly exceeds the area of productive forest land.

Wolf Lake-Emerson Corridor

This corridor crosses three vegetation formations--Boreal Forest, Parkland (Aspen and Aspen-Bur Oak), and Grassland (Figure 8.1.2.4-6).

The Boreal Forest, as previously described, is crossed for 210 miles, from Wolf Lake to a point southwest of Shellbrook, Saskatchewan (Figure 8.1.2.7-2). Near Shellbrook the corridor enters Aspen Parkland and remains within it for about 275 miles, to a point a few miles west of the Saskatchewan-Manitoba border where it enters Aspen-Bur Oak Parkland.

The corridor length of 232 miles in Aspen-Bur Oak Parkland to Emerson, Manitoba, is interrupted twice by the occurrence of vegetation of other formations. East of Brandon there is a crossing of about 25 miles of an outlying body of Boreal Forest mixedwoods, the site of the Sprucewoods Provincial Forest. Southwest of Winnipeg, the corridor crosses about 35 miles of cropland, orginally tall grass prairie, before again entering Aspen-Oak Parkland for approximately 5 miles to the terminus of the corridor at Emerson.

The Aspen Parkland was originally a grove-like mixture of trembling aspen within grassland. The principal grassland communities were fescue (*Festuca scabrella*) and spear grass-wheat grass (*Stipa spartea* var. *curtiseta*-*Agropyron dasystachyum*).

The size and quality of aspen declines with approach to the grassland and to the south is found scattered on low bluffs, in depressions, and around sloughs.

In the Aspen-Bur Oak Parkland the dominant grasses were wheat grass and needlegrass species. Aspen occurs as small patches of bushy trees around wet depressions and forms continuous stands only along the northern border of the Parkland. Bur oak (*Quercus macrocarpa*) is common along rivers and on shallow dry soils of south and west slopes. White elm (*Ulmus americana*) is common on alluvial soils and is associated with green ash (*Fraxinus pennsylvanica* var. *subintegerrima*), cottonwood (*Populus deltoides*), basswood (*Tilia americana*), black ash (*Fraxinus nigra*) and Manitoba maple (*Acer negundo*).

The natural vegetation of tall grass prairie, crossed by the Treherne segment of the corridor in Manitoba, has essentially disappeared as a consequence of intensive wheat and mixed grain agriculture. Throughout the Parkland the most favorable grassland areas are also under cultivation and livestock grazing utilizes much of the remainder.

Wolf Lake-Crowsnest Corridor

The corridor begins in the Boreal Forest Formation, as previously described. The vegetation for the first 80 miles was originally aspen-spruce mixedwood forest but the area is now largely devoted to agriculture. About half of the area along this segment, centered about the North Saskatchewan River (Figure 8.1.2.7-4), is more than 50 percent under cultivation.

The next 135 miles, to about the crossing of the Red Deer River about 30 miles north of Drumheller, lies within Aspen Parkland in which trembling aspen is intermixed with needlegrass-fescue grassland. Throughout this segment the land is now more than 50 percent under cultivation.

The corridor next crosses about 120 miles of the Grassland Formation, somewhat interrupted at the southern end by small outlying patches of Aspen Parkland. The original grassland was of medium grasses among which wheat grass, grama grass, and needlegrass were the principal dominants. Characteristically groves of aspen were scattered through this part of the grassland. With minor exceptions the land of this segment is more than 50 percent under cultivation.

The last 50 miles of the 385-mile-long corridor lies within the Subalpine Forest Formation. The forests are Engelmann spruce, white spruce, and their hybrids. Alpine fir is abundant at higher altitudes in the older spruce forests. Lodgepole pine is an important associate of spruce and replaces it over large areas following forest fires. At lower elevations alpine larch (Larix lyallii) is mixed with lodgepole pine and hybrid spruce and also occurs on exposed ridges and slopes at treeline.

Dome and Brandon Corridors

The Moose Jaw segment and most of the Dome segment (Figure 8.1.2.7-5) lie within the Grassland Formation. A short part of the Dome segment crosses outlying patches of Aspen-Bur Oak Parkland and the Brandon segment crosses extensive areas of both grassland and parkland communities.

With the exception of the vegetation of two sand dune areas, totaling about 25 miles of right-of-way crossing, the dominant grass species of the Moose Jaw segment are wheat grass (Agropyron spp), spear grass (Stipa spp) and blue grama (Bouteloua gracilis). In moist areas, on slopes protected from the sun, in sandhills, and on elevated ground, trembling aspen occurs in small stands.

The vegetation of the sand dunes may include grasses characteristic of the mixed prairie and a large number of forb species. On stabilized dunes characteristic shrubs are creeping juniper (Juniperus horizontalis), bearberry (Arctostaphylos uva-ursi), rose (Rosa spp), western snowberry (Symphoricarpos occidentalis)and choke cherry (Prunus virginiana). One dune area begins about 30 miles east of the origin of the segment and extends a distance of about 15 miles. The second area is about 10 miles in width and lies about 10 miles west of Moose Jaw along Thunder Creek.

Vegetation along the stream valleys includes the dominant trees of the Aspen-Oak Parkland and such shrubs as sand bar willow (Salix interior), high bush cranberry (Viburnum trilobum), red osier dogwood (Cornus stolonifera), and red elderberry (Sambucus pubens).

Crossing the sand dune complex and Thunder Creek, the corridor enters grassland with dominants of wheat grass and june grass (Agropyron dasystachyum-Koeleria cristata). From Keystone (Figure 8.1.2.7-5), for about 60 miles, the Dome segment lies in the wheat grass-june grass prairie and for about the next 60 miles crosses mixed prairie of spear grass-wheat grass and spear grass-blue grama-wheat grass. This prairie contains numerous sloughs and moist prairie vegetation types. Many species of grasses, sedges and rushes are typical of the sloughs which also may be ringed by willows and aspen.

The terminal 63 miles of the Dome segment to Elmore, Saskatchewan, cross mixed prairie of spear grass-wheat grass or fescue. This prairie characteristically had scattered aspen groves and a large component of slough-moist prairie communities, as mentioned previously.

This type of prairie would also be crossed by the Brandon segment in Saskatchewan, except for the first 30 miles which would lie in wheat grass-june grass prairie, and a 50-mile crossing of an Aspen-Oak Parkland outlier. The latter is a 100-mile, linear, east-west trending, body of parkland that lies roughly between Indian Head and Moosomin, Saskatchewan (Figures 8.1.2.7-5 and 8.1.2.4-6).

In Manitoba, the Brandon segment continues in mixed prairie for about 34 miles and then crosses about 38 miles of Aspen-Oak Parkland to Moorepark and the junction with the Wolf Lake-Emerson Corridor.

Throughout the corridor, cropland and improved or rough pasture for livestock grazing have taken over most of the natural vegetation.

Wildlife

Fish

Wolf Lake Corridors--The Liard River-Wolf Lake Corridor is in the Mackenzie River drainage and the fishery resources are similar to those described for the proposed route (Section 2.1.2.7). Continuing from Wolf Lake, the corridor to Emerson passes through or along the eastern side of grazing and wheatland areas which, on the western side, are crossed by the proposed Monchy Delivery Line.

The Wolf Lake-Emerson Corridor lies within the Hudson Bay drainage as does the Wolf Lake-Crowsnest Corridor, for the most part. The fishery resources are similar to those along the proposed Monchy Delivery Line, as previously described (Section 2.1.2.7).

Dome and Brandon Corridors--These corridors also pass through agricultural and grazing land. Both lie within the Hudson Bay drainage. The fishery resources are the same as for the Monchy Delivery Line (Section 2.1.2.7).

Mammals and Birds

Wolf Lake Corridors--The kinds of mammals and birds found along these corridors through the Provinces of Alberta, Saskatchewan, and Manitoba are generally the same as those found along comparable segments of the proposed route. The Liard River-Wolf Lake Corridor mainly traverses Boreal Forest of the mixedwoods type (spruce-aspen-birch). Approximately 170 species of breeding birds and 35 wintering species have been reported to inhabit this type of forest in Alberta. Moose, snowshoe hare, lynx, red fox, wolf, and wolverine are typical mammal species expected to occur. These species also occur along the proposed route between Fort Simpson and Caroline Junction.

The Wolf Lake-Emerson Corridor begins in the Boreal Forest in central Saskatchewan and passes through the eastern edge of the mixed grazing and wheatland area of southern Saskatchewan. Gray partridge are indicative of the agricultural areas and sharp-tailed grouse are typical of the interspersed grasslands. Extending west past the Monchy Delivery Line, extensive prairie pothole areas are key waterfowl breeding habitat. These waterfowl breeding areas are among the most productive and important waterfowl nesting grounds on the North American Continent. The species of birds and mamals are similar to those encountered on the Monchy Delivery Line of the proposed route, as previously discussed (Section 2.1.2.7).

The mammal and bird resources of the Wolf Lake-Crowsnest Corridor are similar to those along the Kingsgate Delivery Line, as previously described (Section 2.1.2.7).

Dome and Brandon Corridors--These corridors cross the same kind of agricultural and grazing lands characteristic of the southern end, especially the Treherne segment, of the Wolf Lake-Emerson Corridor. They also traverse the same prairie pothole areas which are critical waterfowl breeding grounds. The bird and mammal resources are similar to those previously described for the Monchy Delivery Line (Section 2.1.2.7).

Ecological Considerations

Liard River-Wolf Lake Corridor

This corridor, with minor exceptions, lies within the Boreal Forest Ecosystem. The major communities crossed are generally similar to those of the proposed route as previously discussed (Section 2.1.2.8) for the area between Fort Simpson, N.W.T., and Caroline, Alberta.

Wolf Lake-Emerson Corridor

The first 210 miles of the corridor continues from Wolf Lake within the Boreal Forest Ecosystem. The remainder of the corridor crosses the Parkland Ecosystem and about 35 miles of former Grassland Ecosystem, now under cultivation, near Emerson, Manitoba. These ecosystems are similar to those of the Monchy Delivery Line (Section 2.1.2.8).

Wolf Lake-Crowsnest Corridor

This corridor begins at Wolf Lake as a short segment within the Boreal Forest Ecosystem and successively crosses Aspen Parkland, Grassland, and Subalpine Forest Ecosystems. These have been previously discussed for the Monchy and Kingsgate Delivery Lines (Section 2.1.2.8). Both parkland and grassland are urbanized or heavily utilized for cropland and grazing land.

Dome and Brandon Corridors

These corridors occur in remnant Grassland and Parkland Ecosystems or agricultural and grazing lands which have displaced them. The Moose Jaw segment lies within the former Grassland Ecosystem, as does the Dome segment, excepting minor crossings of outliers of Aspen-Bur Oak Parkland Ecosystem in southeastern Saskatchewan. The Brandon segment crosses extensive areas of both Grassland and Parkland Ecosystems.

The corridors are very similar to the Monchy Delivery Line of the proposed route (Section 2.1.2.8).

Economic Factors

The economy of Alberta, Saskatchewan and Manitoba has been based for many years on agriculture, oil, gas and coal exploration and production, some other mining, and timber harvest. Pipelines for gas and oil transport have been in use in this region for many years. The multibased economy, supporting services, transportation network, and Provincial and local government functions are believed to be well integrated and capable of absorbing new activities without serious impact problems.

Sociological Factors

The population of Alberta and Saskatchewan has risen from 164,300 in 1901 to about 1,771,230 in 1951 and 2,554,115 in 1971. Saskatchewan's population has decreased since 1966 while that of Alberta has increased. The 1974 population estimates indicate that these trends are continuing with a small net increase over 1971.

In 1951 there were approximately 22,250 people in Saskatchewan and 21,163 in Alberta who were listed as Indian. (All figures from Canada Population Statistics.)

No specific information is furnished on community structure, housing characteristics, educational system, or health and waste disposal services. In view of the long-established rural and urban settlement in these Provinces, and the several large urban centers, these sectors are assumed to be at least adequate for current needs.

Land Use

By analogy with similar regions near the proposed route (Section 2.1.2.11), land-use patterns in the region of the Southern Canada Corridors are very similar to those along the proposed route, particularly along the Wolf Lake-Emerson, Wolf Lake-Crowsnest, Dome and Brandon Corridors, where agriculture is the main industry. The Liard River-Wolf Lake Corridor is only scantily served by transportation routes at present, but the agricultural areas to the south which include some of the most thoroughly developed areas in southern Canada have good networks of roads, railroads, and petroleum pipelines.

Paleontological, Archeological, and Historic

Most parts of the Southern Canada Corridors cross areas that are to a large extent settled or otherwise developed. In such areas, it is assumed the majority of archeological and historic sites have long since been discovered and preserved or destroyed by construction activities.

Recreation and Esthetic Resources

Along the Liard River-Wolf Lake Corridor the landscape is mostly low, rolling, forested terrain interrupted by watercourses and ranges of hills and mountains. The area is sparsely populated, with few roads and other transportation facilities, but is well suited to fishing and hunting which are the principal recreation activities of both the resident and non-resident populations.

The other corridors cross mostly more settled areas, where agriculture and other works of man predominate in generally smooth-surfaced terrain on the plains, and existing or potential outdoor recreation areas and facilities are not common except near several large lakes. A corner of Meadow Lake Provincial Park is about 10 miles from the Wolf Lake-Crowsnest corridor in western Saskatchewan.

Air Quality

Data presented in the discussion of air quality in the region traversed by the proposed route (Section 2.1.2.14) are generally applicable to the Southern Canada Corridors. The major man-caused pollutant probably is dust in agricultural areas and is derived from freshly plowed and fallow fields. Emissions from internal combustion engines, both mobile and stationary, would be important locally near transportation routes and population centers, but pollutants would be rapidly dissipated.

Environmental Noise

The general discussion of environmental noise along the proposed route (see Section 2.1.2.15) is also applicable to the Southern Canada Corridors. Ambient sound levels along most of the Liard River-Wolf Lake Corridor are probably similar to those along the proposed route north of 59° N latitude. Along the other corridors, ambient sound levels are probably more like those along the proposed route south of 59° N latitude.

Evaluation of the Environmental Impacts

Climate

There would be no climatic impacts of regional scope if a gas pipeline system were constructed in any of the Southern Canada Corridors. Any possible local impacts probably would be infinitesimal.

The impact of climate on construction and operation of a pipeline and ancillary facilities would be the same for these corridors as for equivalent latitudes of the proposed route, as previously described (Section 3.1.2.1).

Topography and Geology

The Southern Canada Corridors cross terrain similar to that of the southern half of the proposed route; consequently, the types of environmental impacts are essentially the same as those affecting that part of the proposed route. These impacts are described in Section 3.1.2.2 and 3.1.2.3.

Mineral Resources

Metallic and Nonmetallic Mineral Resources--Construction and operation of a pipeline system using any of the Southern Canada Corridors would entail the consumptive use of some geologic materials, as for construction purposes. There would be few if any impacts on the exploitation of other nonmetallic or metallic mineral resources because, by the nature of the known commodities and deposits, they probably would be recovered by underground methods that would not be in conflict with surface land uses such as those involved in pipeline construction and operation.

Coal--The only impact that construction and operation of a gas pipeline system might have on use of the coal resources of the Southern Canada Corridors would be the denial to strip mining of the land actually used for pipeline right-of-way, appurtenant installations, and pit-slope maintenance. At most this would entail only a very small fraction of the potential coal land in the region.

Oil and Gas--Use of the Southern Canada Corridors should not significantly affect current production and transmission of Canadian oil and gas.

Soils

Clearing of vegetation and disturbance of the soil surface would cause increased erosion. However, the Southern Canada Corridors traverse mostly level to rolling terrain and the problem of increased erosion is important but, except near stream crossings, it would not be as great as in steeper terrain.

Along the Liard River-Wolf Lake Corridor disruption of irrigation activities would not be of major importance because land use is limited almost completely to pasture and woodland. South of Wolf Lake Junction such disruption could cause some impact of brief duration during construction.

Water Resources

The degree of potential impact would depend upon the design and the measures taken during construction to minimize the impacts. Four areas of concern are: (1) channel erosion, (2) icings, (3) depletion of streamflow during construction, and (4) drainage disruption (see Table 3.1.2.5-1 for a general summary of impact mechanisms and possible consequences).

The primary impact on ground water in the corridors would be the disturbance of the shallow aquifer during pipeline construction and operation. Disturbance of this aquifer will affect ground-water flow patterns resulting in accelerated erosion and possible contamination. Another potential for impact on ground water would be the discharge of liquid wastes and leaching of sanitary landfills.

Vegetation

Wolf Lake Corridors

The principal impacts previously discussed for the proposed route (Section 3.1.2.6) would apply to these corridors. Widespread permafrost in the Great Slave Plain, decreasing in distribution into the Provinces, implies the usual concern for disturbance of the moss-peat layer, thermal erosion, disruption to drainage, cut-grading at stream crossings, and proper construction and use of snow roads. Numerous stream crossings occur, including the Hay, Peace, and Athabasca Rivers within the area of discontinuous permafrost.

The floodplains and terraces along these rivers have well-developed highly productive forests of white spruce which support the lumbering industry. A sawmill and railhead are located at High Level (CAGPL, 1974d,6, p. 27) near the corridor in Alberta.

The principal impact of pipeline construction on the forests would be the clearing of trees from the right-of-way, construction sites, and the riverbanks at stream crossings.

Fire susceptibility would exist through all but vegetation of wetter sites for the lengths of the corridors. The Aspen Grove Section of the Boreal Forest is entered at about the Saskatchewan River and from there to Emerson the corridor lies in mixed aspen and prairie, now largely devoted to agriculture and grazing. If a pipeline were constructed in this corridor, river crossings would involve the removal of bur oak, balsam poplar, ash, elm and other hardwoods from the right-of-way.

Throughout the extensive agricultural lands the impact of construction on remnant natural vegetation would consist of removal of trees from the right-of-way and the destruction of natural vegetation over the ditch line. Production would be lost for a short time on the right-of-way passing through cultivated land. Farming of the right-of-way could be resumed after 1 year and grazing probably after 2 years.

The Wolf Lake-Crowsnest Corridor begins in Boreal Forest and ends in Subalpine Forest, but otherwise lies within remnant grassland communities, Parkland, or agricultural and grazing lands. The impacts of the Crowsnest Corridor on vegetation would be the same as described for the Kingsgate Delivery Line (Section 3.1.2.6). The impacts of the other corridors on vegetation would be the same as discussed for the Monchy Delivery Line (Section 3.1.2.8).

Major Plant Communities Affected--The 618-mile-long Liard River-Wolf Lake Corridor lies within the Boreal Forest except for crossings of about 10 miles of grassland along the Hay River and about 30 miles of Aspen Parkland in the Fort Vermilion region. Based upon average figures, the acreages of vegetation affected would be as follows:

	Right-of-way	Facilities	Total
Boreal Forest	8,339	1,882	10,221
Grassland	144	33	177
Aspen Parkland	433	98	531
Total	8,916	2,013	10,929

The acreages of land used for the 717-mile-long corridor from Wolf Lake to Emerson would be distributed approximately as follows:

	Right-of-way	Facilities	Total
Boreal Forest	3,391	765	4,156
Aspen and Oak Parkland	6,449	1,456	7,905
Grassland	505	114	619
Total	10,345	2,335	12,680

The acreages of land used for the 385-mile-long Wolf Lake-Crowsnest Corridor would be approximately as follows:

	Right-of-way	Facilities	Total
Boreal Forest	1,154	260	1,414
Aspen Parkland	1,948	439	2,387
Grassland	1,731	391	2,122
Subalpine Forest	722	163	885
Total	5,555	1,253	6,808

Dome and Brandon Corridors

The impacts on these corridors would be similar to those of the southern parts of the Wolf Lake Corridors and of the Monchy Delivery Line (Section 3.1.2.8).

Major Plant Communities Affected--The 218-mile Moose Jaw segment, entirely within the Grassland Formation and now largely agricultural land, would occupy approximately 3,145 acres for right-of-way and 710 acres for related facilities; and the 183-mile-long Dome segment would require land acreages approximately as follows:

	Right-of-way	Facilities	Total
Grassland	1,731	391	2,122
Aspen-Oak Parkland	909	205	1,114
Total	2,640	596	3,236

The acreages of land required for the 233-mile Brandon segment would be distributed approximately as follows:

	Right-of-way	Facilities	Total
Grassland	2,092	472	2,564
Aspen-Oak Parkland	1,270	286	1,556
Total	3,362	758	4,120

Wildlife

The potential impacts are similar to those described for various segments of the proposed route in Section 3.1.2.7. The Liard River-Wolf Lake Corridor is similar to the Fort Simpson-Caroline Junction segment of the proposed route; the Wolf Lake-Crowsnest Corridor is similar to the proposed route in the vicinity of Caroline Junction and southward along the proposed Kingsgate Delivery Line. The Wolf Lake-Emerson, Brandon, and Dome Corridors are similar to the Monchy Delivery Line segment of the proposed route. In addition, the impacts are similar to those described in Section 3.1.3.7 of the North Border volume of this EIS for adjacent areas in the United States.

The Dome and Brandon Corridors pass through critical waterfowl nesting areas as does the Monchy Delivery Line. These waterfowl production areas are some of the most important in North America and could be seriously affected by drainage changes and by noise and other disturbances during the nesting season. Production would be lost for one season in potholes actually crossed and permanently, in the event a pothole were drained.

Ecological Considerations

The nature of impact on ecosystems has been discussed for the proposed route (Section 3.1.2.8) and the comments are generally applicable to these corridors.

Economic Factors

If the proposed pipeline were built along any of the Southern Canada Corridors the impact would probably be relatively small on the overall economic activities, employment and income, and local tax base and revenue. In Alberta the northern half of the corridors passes through sparsely settled country and the southern half of the corridors lies east of the major cities of Edmonton and Calgary through an area of smaller communities that has many known and developed gas and oil fields.

Corridors in Saskatchewan in general pass through areas of small communities. One corridor is about 50 miles from the major city of Saskatoon, and other corridors pass within several miles of Regina. The Wolf Lake-Emerson Corridor passes about 50 miles from Winnipeg.

Undoubtedly the employment, cash flow, and tax base that the proposed project could generate would benefit the overall economy. It seems reasonable to assume that pipeline construction and operation activities would be accommodated readily by the existing economy with a net beneficial impact. Adverse impacts could affect that portion of the economy related to recreational activities such as hunting and fishing.

Sociological Factors

The probable future overall trends of population should not be materially altered by the proposed pipeline project if it followed any of the Southern Canada Corridors. Saskatchewan, which has shown a declining population trend in recent years, might be expected to derive a relatively greater benefit than Alberta. Some of the small communities that would be close to operational and maintenance bases might derive a relatively large stimulus to their housing and service sectors.

Land Use

Impacts on the Southern Canada Corridors would be restricted to the dedication of land for the life of the project for ancillary facilities such as compressor stations and borrow pits. Clearing of timber would make lumbering in the right-of-way impossible until long after the project had terminated. South of Wolf Lake Junction the major short-term impact during the construction period would be the removal of right-of-way from cultivation or any other use except deep mining.

Paleontological, Archeological, and Historic

Sites along the Southern Canada Corridors that have not already been destroyed by the works of man could be damaged or destroyed by pipeline construction.

Recreation and Esthetic Resources

Construction of a pipeline in the Southern Canada Corridors would have the most visual impact along the segment north of Wolf Lake Junction. South of this point, the corridors cross mostly settled land. If a pipeline were constructed, impact on recreation resources would probably be minor except during the construction period, when road congestion, dust, smoke, and noise could detract from the quality of nearby recreation sites.

Air Quality

If a gas pipeline system were constructed in the Southern Canada Corridors, impacts on air quality would be minor and ephemeral and similar to those described in the discussion of the proposed route (Section 3.1.2.14).

Environmental Noise

Noise impacts along the Liard River-Wolf Lake Corridor would be similar to those along the proposed route north of 59° N latitude. Along the other corridors, the noise impacts would be more like those along the proposed route south of 59° N latitude (see Section 3.1.2.15).

8.1.2.8 Alternative of 42-inch Supply Lines

On March 10, 1975, Canadian Arctic Gas Pipeline Limited amended earlier applications to the Government of Canada by requesting approval of smaller diameter supply lines from Alaska and the Mackenzie Delta region. Approximately 440 miles of pipeline would be affected in Canada. A description of the design change and evaluations of its environmental impact are presented in this section.

Description of the Action

Under the amended design, the Applicant would construct both the Prudhoe Bay and Richards Island Supply Lines from pipe having an outer diameter of 42 inches and wall thickness 0.63 inch (CAGPL, 1975b, 8.b.1.2, p. 8). Like the 48-inch pipe previously proposed, the pipe would have a specified minimum yield strength of 70,000 psi and would operate at a maximum pressure of 1,680 psig. Using 42-inch pipe for the supply lines would not involve changes in the proposed route or in many other features of the design north of Travaillant Lake Junction; locations and designs of compressor stations, communication facilities, borrow sites, block values and access roads would be unaffected. However, changes in the number of compressor stations required by the fifth operating year would result from the design amendment.

Compressor stations CA 05 and CA 09, needed in the second operating year on the Canadian part of the Prudhoe Bay Supply Line under the 48-inch design, would not be built during the first 5 operating years under the 42-inch design; they might be required at a future, unspecified date, however. Instead, compressor stations CA 06, CA 08 and CA 10 would be required for operation in the second year of transmission. The measuring station planned for construction at CA 05 under the 48-inch design would be placed at CA 04 under the 42-inch design. On the Richards Island Supply Line, whereas formerly no compressor stations would be needed during the first 5 operating years, compressor station M 02 would be built for operation during the second year of transmission through the 42-inch pipeline. Thus on the supply lines in Canada, a total of 4 compressor stations would be required under the 42-inch design whereas only 2 were required under the 48-inch design.

The increased number of compressor stations called for in the 42-inch design would enable the supply lines to transmit the same quantity of gas: 2.25 MMcfd (CAGPL, 1974a, CAGPL, 1975b, 8.b, p. 2). Under the 42-inch design, however, total system throughput would be decreased by approximately 0.4 percent because of added amounts of gas consumed in operating the additional compressor stations.

The extent to which transmission capacity could be increased without looping differs significantly in the two designs. The 48-inch supply line throughput could be doubled by the addition of compressor stations (CAGPL, 1974a, 8.b.1.1) whereas the capacity of the 42-inch supply lines could be increased only 40 percent (CAGPL, 1975b, 8.b, p. 4).

By building 42-inch supply lines Canadian Arctic Gas Pipeline Limited would realize cost savings amounting to approximately $200,000,000 (Canadian) (comparison between CAGPL, 1974b, 10, p. 1, and CAGPL, 1975b, 10, p. 1-12). Slightly higher operating costs would result from the 42-inch design because of requirements for two additional technicians (CAGPL, 1975b, 13.b, p. 2).

Evaluation of the Environmental Impacts

The environmental impacts that would result from construction and operation of the smaller supply pipelines would not differ from those described for the 48-inch supply lines in this Statement. The impacts from the construction and operation of compressor stations during the first 5 operating years would increase approximately 2-fold, however, in direct response to doubling the number of compressor stations called for in the 42-inch design. The main impacts during the construction of the compressor stations would be increased requirements for borrow for gravel pads, terrain disturbances leading to permafrost thaw, transient decreases in air and water quality resulting from waste discharge and siltation, and disturbances to wildlife resulting from presence of construction camps, operation of heavy equipment, and air and ground traffic. The main impacts during the operational phase of compressor stations would be continued thawing of permanently frozen ground disturbed during construction, local decreases in air quality by exhaust gases from compressor turbines and refrigeration plants, and disturbances to wildlife resulting from the noise of station operation and visits of maintenance and repair personnel.

The environmental impacts of the 42- and 48-inch supply line systems could differ significantly if increased gas supplies and demands provided incentives for expanding the transmission volume. If the 42-inch supply lines were built, throughput could not be expanded beyond approximately 5,909 MMcfd without construction of second, parallel pipelines (looping). However, the 48-inch pipelines could deliver 8,475 MMcfd without looping. If looping of the supply lines occurred, most of the environmental impacts resulting from the first construction and operation would happen again. The amount and severity of impacts might be somewhat less, however, because the second line would be located near the first and because separate compressor station locations probably would not be required.

Thus, should additional large reserves of natural gas be discovered in Alaska and the Northwest Territories, construction of 42-inch supply lines would increase the likelihood of a second episode of pipeline construction.

8.1.2.9 Summary of Impacts for All Alternatives

Introduction

Ten routes or corridors are discussed in this section; one is the proposed route and nine are possible alternative routes or corridors (Figures 8.1.2-1 and 2). Five of the alternatives to the proposed route (Interior Route, Fort Yukon Corridor, Cross-Delta Route, Fairbanks Corridor, and the Wolf Lake Corridors) would be overland pipeline systems across Canada; the Dome and Brandon Corridors would be alternatives only to the Monchy Delivery Line. The Haines Option and Babbage Bight Corridors would require transshipment of liquefied natural gas from marine terminals. The Offshore Corridor, discussed in the Alaska volume, is not included in this summary. All routes and corridors are described briefly in Section 8.1.2, and nine of the ten alternatives to the proposed route are discussed fully in Sections 8.1.2.1 through 8.1.2.7. Impact of LNG transshipment is discussed in the Alternatives volume of this Statement.

An additional alternative, use of 42-inch rather than 48-inch supply lines is described in Section 8.1.2.8. However, "(t)he environmental impacts that would result from construction and operation of the smaller supply pipelines would not differ from those described for the 48-inch supply lines...". Adoption of the 42-inch supply lines seems to be an economic rather than an environmental issue, hence further discussion of this alternative does not seem warranted here.

In the preceding sections on alternative routes and corridors (8.1.2.1 through 8.1.2.7), major emphasis was placed on those segments which diverge from the proposed route. In the following discussions, however, the data presented for each alternative are based on the full extent of supply, trunk, and delivery lines across Canada. The alternative routes and corridors thus include appropriate portions of the proposed route, as outlined in Section 8.1.2.

Estimated Facilities

Preliminary designs for pipeline systems that could be built in alternative corridors have not proceeded to levels comparable to that for the proposed route (as described in Section 1.1.2) or for the Interior and Cross-Delta Routes. Like these routes, pipeline systems that could be constructed in the alternative corridors would presumably consist of 48-inch pipe and would be planned for transmission of approximately 4.5 bcf/d of natural gas. Ancillary facilities of the systems would also presumably be comparable in type and scale to those for the proposed route.

Table 8.1.2.9-1 presents mileages and numbers of facilities designated for the proposed, Interior, and Cross-Delta routes based on the Applicant's preliminary designs, and hypothetical mileages and numbers of facilities on seven suggested alternative corridors. The hypothetical quantities of facilities in alternative corridors are generally based upon the numbers of facilities per mile along the proposed route. The potential impacts of these facilities would be similar in nature to those along the proposed route, and roughly proportional in quantity to the mileages of the respective corridors. Thus, within Canada facilities along the Fairbanks and Southern Canada Corridors would have substantially greater impacts than those along the proposed route; facilities along the Interior Route and Fort Yukon Corridor would have about the same impacts; and facilities along the Cross-Delta Route, the Haines Option, and the Babbage Bight Corridor would have substantially fewer impacts.

Topography and Geology

Proposed Route

The proposed route is 2,435 miles in length (Table 8.1.2.9-2). Approximately 1,050 miles of this route would closely parallel existing roads or pipelines; an additional 1,000 miles would extend through the Mackenzie Valley, a locus of settlement along the Mackenzie River transportation corridor in northwestern Canada and the site of a major transportation development, the partially completed Mackenzie Highway. The remaining 360 miles consists primarily of wilderness or very lightly developed areas. The proposed route would cross terrain of generally gentle to moderate relief throughout its length except on crossing the Rocky Mountains. The highest point would be about 7,000 feet altitude in southern

Table 8.1.2.9-1 Numbers of facilities and acreage requirements for proposed route and alternative routes and corridors

	Proposed Route 1/	Interior Route 1/	Cross-Delta Route 2/	Fort Yukon Corridor 3/	Fairbanks Corridor 3/	Wolf Lake Corridor 3/	Dome Corridor 3/	Brandon Corridor 3/
Miles of pipeline 4/	2,435	2,378	2,297	2,532	2,826	2,841	2,676	2,863
Right-of-way acreage	35,132	34,220	35,393	36,530	40,772	40,990	38,609	41,307
Compressor stations	50	50	48	51	57	57	55	59
Block valves	60	58	55	145	93	72	62	70
Gas measuring stations	9	9	9	9	9	9	9	9
Communication towers	80	79	76	89	98	99	88	95
Access roads (miles)	550	527	540	950	481	608	566	578
Airstrips	21	19	17	20	25	23	21	21
Helipads	170	170	164	171	192	204	188	201
Wharves	19	16	20	3	3	19	19	19
Stockpiles	26	33	25	52	21	31	28	30
Borrow pits	108	108	90	121	142	109	108	108
Campsites	37	33	34	49	64	35	37	37
Additional acreage for facilities	7,928	7,321	7,469	8,247	9,298	8,898	8,452	8,943
Total acreage	43,060	41,541	42,862	44,777	50,070	49,888	47,061	50,250

1/ Source: 1974 CAGPL, Section 13.a, Subsection 14.e.1.10.
2/ Source: 1975 CAGPL Supplement, Alaska supply lateral across Mackenzie Delta, Section 13a.
3/ Estimated on basis of facilities along proposed route.
4/ Mileages for alternate routes and corridors include coincident portions of the proposed route.

Table 8.1.2.9-2 Physical setting, proposed route

Corridor segment	Length (miles)	Miles along existing roads or pipelines	Wilderness areas[1] (miles)	Agricultural areas[2] (miles)	Mountain crossings (elev. in ft)	Stream crossings		Remarks
						Minor[3]	Major[3]	
Prudhoe Bay Supply Line	297	1	239	0	-	253	10	Crosses regional drainage
Richards Island Supply Line[4]	158	12	94	0	-	90	1	
Main Line N. of 60° N Latitude	695	2	519	10	-	103	14	Traverses Mackenzie Valley
Main Line S. of 60° N Latitude	610	460	52	56	-	188	11	
Monchy Delivery Line	394	328	0	241	-	147	6	
Kingsgate Delivery Line	281	251	0	40	7,000, 6,500 6,300, 5,900 5,800	131	6	Crosses Canadian Rockies
Totals	2,435	1,054	904	347	5 > 5,000 ft	912	48	

[1] Areas more than 10 miles distant from towns, roads, airfields, and other developments.

[2] Does not include isolated small fields and homesteads.

[3] Drainage basins smaller and larger than 300 mi^2, respectively.

[4] Includes Parsons Lake Lateral Line (15 miles).

Canada. The proposed route crosses 46 major streams or rivers, defined as possessing a drainage basin greater than 300 square miles above the route crossing. It would cross approximately 347 miles of agricultural lands in Alberta and Saskatchewan.

The proposed route would cross extensive areas of potential geologic hazards from permafrost, earthquakes, and mass movements (Table 8.1.2.9-3). Approximately 1,241 miles of the route would cross terrain that might be expected to contain permafrost. An estimated 525 miles of permafrost is likely to be ice-rich, resulting in such potential environmental impacts as accelerated erosion, differential settlement, and increased requirements for gravel-pad foundations. About 1,458 miles of the route crosses slopes of less than 10 percent grade, while roughly 56 miles occupies slopes steeper than 25 percent. Major hazards from mass wasting exist along 1,044 miles of the route, and moderate hazards along an additional 983 miles. This large total results from the very extensive areas of shale and silt- to clay-rich surficial deposits and the general instability of such materials even on gentle slopes, especially where there is a potential for thawing permafrost. Locally, expansive clay minerals might increase the severity of mass movements in parts of Saskatchewan and Alberta. Potential hazards from severe earthquakes (magnitude 7.0) exist along 166 miles of the route. Such earthquakes could break or damage the pipeline either directly by ground motion or indirectly by landslides or subsidence triggered by ground shaking. Additional hazards to the pipeline include stream icings (aufeis) at river and stream crossings in the northern one-third of the route and flooding at crossings throughout the entire length of the route.

Interior Route

The 2,378-mile-long Interior Route would extend across the Richardson Mountains and intersect the proposed route near Fort McPherson, N.W.T. (Table 8.1.2.9-4). Approximately 1,050 miles would parallel existing roads or pipelines, and nearly 1,000 additional miles would lie near the proposed Mackenzie Highway. About 300 miles of the route would cross areas essentially untouched by human activity. The Interior and proposed routes would cross the same agricultural areas in Alberta and Saskatchewan. The Interior Route would cross the Richardson Mountains prior to joining the proposed route, then would follow the course of the proposed route through the relatively gentle slopes of the Mackenzie Valley. It would cross 43 major streams or rivers.

The Interior Route would cross approximately 1,184 miles of terrain that might be expected to contain permafrost (Table 8.1.2.9-5). About 428 miles of the route would cross areas that are likely to be ice-rich and could pose a potentially serious hazard to the integrity of a pipeline if the enclosed ice were to melt. Approximately 1,383 miles of the Interior Route crosses slopes of less than 10 percent grade; only 52 miles of the route cross slopes steeper than 25 percent. Major hazards from mass wasting exist along approximately 927 miles of the route, and moderate mass-wasting hazards occur along approximately 998 miles. Potential hazards from severe earthquakes (magnitude 7.0) exist along about 100 miles of the route, and potentially damaging earthquakes (magnitude 5.0 to 6.5) could occur along an additional 1,383 miles. Other hazards along the Interior Route include aufeis at river and stream crossings in the northern one-third of the route and flooding at crossings throughout the route.

Table 8.1.2.9-3 Potential geologic hazard zones, proposed route

Corridor segment	Length (miles)	Permafrost zones and character (miles)[1]					Slope categories (miles)				Mass-movement zones (miles)[2]		Zones of potential earthquake hazard (mi)						Special or unique hazards
		C	D	S	N	IR	<1%	1-10%	10-25%	>25%	Moderate	Major	4.5	5.0	5.5	6.0	6.5	7.0	
Prudhoe Bay Supply Line	297	297	0	0	0	262	224	64	5	4	10	287	0	40	91	0	0	166	Ice-rich permafrost; seismicity
Richards Island Supply Line[3]	158	158	0	0	0	98	85	66	4	3	15	143	0	53	105	0	0	0	Ice-rich permafrost
Main Line N. of 60° N Latitude	695	24	534	137	0	165	448	224	14	9	187	489	136	309	0	250	0	0	Spontaneous combustion in coal; subsidence in limestone
Main Line S. of 60° N Latitude	610	0	0	74	536	0	347	242	12	9	462	86	365	0	245	0	0	0	Spontaneous combustion in coal
Monchy Delivery Line	394	0	0	0	394	0	219	153	12	10	263	20	394	0	0	0	0	0	
Kingsgate Delivery Line	281	0	0	17	264	0	135	106	19	21	46	19	0	0	281	0	0	0	Mountain slopes
Totals	2,435	479	534	228	1,194	525	1,458	855	66	56	983	1,044	895	402	722	250	0	166	

[1] C - Continuous permafrost.
D - Discontinuous permafrost.
S - Sporadic permafrost.
N - Permafrost generally absent.
IR - Ice-rich permafrost.

[2] Includes effects of thawing permafrost.

[3] Includes Parsons Lake Lateral Line (15 mi).

Table 8.1.2.9-4 Physical setting, Interior Route

Corridor segment	Length (miles)	Miles along existing roads or pipelines	Wilderness areas[1] (miles)	Agricultural areas[2] (miles)	Mountain crossings (elev. in ft)	Stream crossings		Remarks
						Minor[3]	Major[3]	
Alaska border to Travaillant Lake Junction	240	0	155	0	2,600	77	5	Crosses Peel and Mackenzie Rivers, and Richardson Mtns.
Richards Island Supply Line[4]	158	12	90	0	0	90	1	Crosses East Channel of Mackenzie River
Proposed Route south of Travaillant Lake Junction	1,980	1,041	0	347	7,000, 6,500 6,300, 5,900 5,800	569	37	
Totals	2,378	1,053	245	347	5 crossings >5,000	736	43	

---

[1] Areas more than 10 miles distant from towns, roads, airfields, and other developments.

[2] Does not include isolated small fields and homesteads.

[3] Drainage basins smaller and larger than 300 mi^2, respectively.

[4] Includes Parsons Lake Lateral Line (15 miles).

Table 8.1.2.9-5 Potential geologic hazard zones, Interior Route

Corridor aegment	Length (miles)	Permafrost zones and character (miles)[1]					Slope categories (miles)				Mass-movement zonea (eat. mi)[2]		Zones of potential earthquake hazard (mi)						Special or unique hazards
		C	D	S	N	IR	<1%	1-10%	10-25%	>25%	Moderate	Major	4.5	5.0	5.5	6.0	6.5	7.0	
Alaska border to Travaillant Lake Junction	240	240	0	0	0	165	149	90	1	0	25	170	0	40	100	0	0	100	Ice-rich permafrost; aeismicity
Richards Island Supply Line[3]	158	158	0	0	0	98	85	66	4	3	15	143	0	53	105	0	0	0	Ice-rich permafroat
Proposed Route south of Travaillant Lake Junction	1,980	24	534	228	1,194	165	1,149	725	57	49	958	614	895	309	526	250	0	0	
Totals	2,378	422	534	228	1,194	428	1,383	881	62	52	998	927	895	402	731	250	0	100	

[1] C - Continuous permafrost.

D - Discontinuous permafrost.

S - Sporadic permafrost.

N - Permafrost generally absent.

IR - Ice-rich permafrost.

[2] Includes effects of thawing permafrost.

[3] Includes Parsons Lake Lateral Line (15 miles).

Cross-Delta Route

The Cross-Delta Route would coincide with the proposed route except in the Mackenzie Delta, where its alignment would be 139 miles shorter. It would equal the proposed route in miles along existing roads and pipelines and in its extent through mountainous regions and agricultural lands (Table 8.1.2.9-6). It would cross significantly fewer streams than the proposed or Interior routes, but would cross several major distributary channels and embayments of the Mackenzie Delta. Through the distal edge of the delta, it crosses 8 distributary channels 0.1 mile or more in width and up to 75 feet deep. It also crosses an embayment (Shallow Bay) which is 4.5 miles wide.

Geologic hazards along the Cross-Delta Route would differ from those along the proposed route only along the 254-mile stretch in the Mackenzie Delta area where these 2 routes diverge. The shorter distance of the Cross-Delta Route in this area would result in substantial reduction in its distance across ice-rich and continuous permafrost (Table 8.1.2.9-7). The Cross-Delta Route would lie farther from the Richardson Mountains seismic belt than does the proposed route, causing direct seismic hazards to be reduced also. Hazards from major mass movements would be unaffected by the Cross-Delta realignment, but its shorter net length would reduce those moderate mass-movement hazards which occur on gentle slopes and stream banks underlain by ice-rich permafrost. Special geologic hazards might be expected, however, where the Cross-Delta Route crosses the distal edge of the Mackenzie Delta. These hazards could include (1) flooding by storm surges, (2) differential subsidence due to compaction of deltaic sediments, (3) liquifaction due to seismic shocks or other disturbances, (4) rapid shifting by distributary channels, (5) scouring of banks and channels by river and(or) coastal currents, (6) ice jamming during spring breakup, and (7) floods along river channels.

Babbage Bight Corridor

The Babbage Bight Corridor extends about 250 miles along the north coast of Yukon Territory and the distal edge of the Mackenzie Delta (Table 8.1.2.9-8). It follows no existing transport lines, and lies almost entirely within wilderness. There are no mountain crossings nor agricultural areas along this route. The corridor crosses 10 large rivers and 143 lesser streams, thus averages about two stream crossings for every 3 miles of its alignment. It crosses or skirts a large number of thaw lakes.

The Babbage Bight Corridor would lie entirely within the continuous permafrost zone, and as much as 90 percent of its length could cross ice-rich frozen sediments (Table 8.1.2.9-9). Slopes are gentle to moderate, and mass movements would generally be restricted to solifluction and to slides and flows along steep river banks. Except for a possible northern extension of the Richardson Mountains seismic zone, earthquake hazards probably would be minor along this corridor. Aufeis and spring-breakup floods would be hazards along many of the numerous streams crossed by the Babbage Bight Corridor. Additional hazards in the coastal zone would include erosion by waves and currents, siltation of Babbage estuary, flooding by storm surges, and damage to structures by sea ice. As with the Cross-Delta Route, severe geologic hazards could occur along the segment of the corridor which crosses the distal edge of the Mackenzie Delta.

Fort Yukon Corridor

The Canadian portion of the Fort Yukon Corridor extends 2,532 miles, with about 75 percent of this distance closely paralleling existing roads,

Table 8.1.2.9-6 Physical setting, Cross-Delta Route

Corridor segment	Length (miles)	Miles along existing roads or pipelines	Wilderness areas[1] (miles)	Agricultural areas[2] (miles)	Mountain crossings (elev. in ft)	Stream crossings		Remarks
						Minor[3]	Major[3]	
Alaska border to Shingle Point	96	0	96	0	0	73	3	Normal to regional drainage
Shingle Point to Tununuk Junction	82	0	78	0	0	48	5	Crosses distal end of Mackenzie Delta
Richards Island Supply Line	172	0	119	0	0	78	1	Crosses E. Channel of Mackenzie River
Parsons Lake Lateral	15	0	15	0	0	12	0	
Proposed Route south of Thunder River	1,932	1,041	523	347	7,000, 6,500 6,300, 5,900 5,800	549	36	Crosses Canadian Rockies
Totals	2,297	1,041	831	347	5 crossings >5,000	760	45	

---

[1] Areas more than 10 miles distant from towns, roads, airfields, and other developments.

[2] Does not include isolated small fields and homesteads.

[3] Drainage basins smaller and larger than 300 mi^2, respectively.

Table 8.1.2.9-7 Potential geologic hazard zones, Cross-Delta Route

Corridor segment	Length (miles)	Permafrost zones and character (miles)[1]					Slope categories (miles)				Mass-movement zones (est. mi)[2]		Zones of potential earthquake hazard (mi)						Special or unique hazards
		C	D	S	N	IR	<1%	1-10%	10-25%	>25%	Moderate	Major	4.5	5.0	5.5	6.0	6.5	7.0	
Alaska border to Shingle Point	96	96	0	0	0	90	64	28	3	1	10	83	0	0	91	0	0	5	Ice-rich permafrost
Shingle Point to Tununuk Junction	82	82	0	0	0	75	78	2	1	1	5	0	0	0	22	0	0	60	Ice-rich permafrost; delta-front processes; seismicity(?)
Richards Island Supply Line	172	172	0	0	0	155	65	105	1	1	10	160	0	82	90	0	0	0	Ice-rich permafrost
Parsons Lake Lateral Line	15	15	0	0	0	0	6	8	1	0	0	15	0	0	15	0	0	0	Ice-rich permafrost
Proposed Route south of Thunder River	1,932	0	510	228	1,194	153	1,119	709	55	49	944	580	895	261	526	250	0	0	
Totals	2,297	365	510	228	1,194	473	1,332	852	61	52	969	838	895	343	744	250	0	65	

---

[1] C - Continuous permafrost.

D - Discontinuous permafrost.

S - Sporadic permafrost.

N - Permafrost generally absent.

IR - Ice-rich permafrost.

[2] Includes effects of thawing permafrost.

Table 8.1.2.9-8 Physical setting, Babbage Bight Corridor

Corridor segment	Length (miles)	Miles along existing roads or pipelines	Wilderness areas[1] (miles)	Agricultural areas[2] (miles)	Mountain crossings (elev. in ft)	Stream crossings		Remarks
						Minor[3]	Major[3]	
Babbage Bight Spur	15	0	15	0	0	4	1	Crosses Babbage River
Alaska border to Shingle Point	96	0	96	0	0	73	3	Extends normal to regional drainage
Shingle Point to Tununuk Junction	82	0	78	0	0	48	5	Crosses distal end of Mackenzie Delta
Richards Island Supply Line	19	0	19	0	0	8	0	
Parsons Lake Lateral Line[4]	39	0	18	0	0	10	1	Crosses E. Channel of Mackenzie River
Totals	251	0	226	0	0	143	10	

[1] Areas more than 10 miles distant from towns, roads, airfields, and other developments.

[2] Does not include isolated small fields and homesteads.

[3] Drainage basins smaller and larger than 300 mi^2, respectively.

[4] Includes 24-mile stretch of Richards Island Supply Line (Cross-Delta Route).

Table 8.1.2.9-9 Potential geologic hazard zones, Babbage Bight Corridor

Corridor segment	Length (miles)	Permafrost zones and character (miles)[1]					Slope categories (miles)				Mass-movement zones (est. mi)[2]		Zones of potential earthquake hazard (mi)						Special or unique hazards
		C	D	S	N	IR	<1%	1-10%	10-25%	>25%	Moderate	Major	4.5	5.0	5.5	6.0	6.5	7.0	
Babbage Bight Spur	15	15	0	0	0	10	10	5	0	0	2	10	0	0	15	0	0	0	Ice-rich permafrost; coastal erosion
Alaska border to Shingle Point	96	96	0	0	0	90	64	28	3	1	10	83	0	0	91	0	0	5	Ice-rich permafrost
Shingle Point to Tununuk Junction	82	82	0	0	0	75	78	2	1	1	5	75	0	0	22	0	0	60	Ice-rich permafrost; delta-front processes; seismicity(?)
Richards Island Supply Line	19	19	0	0	0	15	18	1	0	0	0	15	0	0	19	0	0	0	Ice-rich permafrost
Parsons Lake Lateral Line[3]	39	39	0	0	0	35	16	23	0	0	4	35	0	0	39	0	0	0	Ice-rich permafrost
Totals	251	251	0	0	0	225	186	59	4	2	21	218	0	0	186	0	0	65	

[1] C - Continuous permafrost.

D - Discontinuous permafrost.

S - Sporadic permafrost.

N - Permafrost generally absent.

IR - Ice-rich permafrost.

[2] Includes effects of thawing permafrost.

[3] Includes 24-mile stretch of Richards Islsnd Supply Line (Cross-Delta Route).

pipelines, or other transportation facilities (Table 8.1.2.9-10). Most of the remaining 610 miles lies more than 10 miles from existing developments, and is considered wilderness. The corridor crosses about 450 miles of agricultural lands in Alberta, Saskatchewan, and British Columbia. The Fort Yukon Corridor follows a series of broad topographic trenches in which relief is gentle to moderate and none of the three mountain crossings exceed 5,000 feet altitude. Farther south, the corridor crosses more rugged terrain of the Canadian Rockies. Five major mountain crossings would be required here, and almost 50 percent of this segment occupies slopes steeper than 10 percent. Throughout its length, the corridor would cross 71 major streams and about 942 minor streams.

The Fort Yukon Corridor would cross about 270 miles of continuous permafrost and an additional 347 miles of the discontinous permafrost zone (Table 8.1.2.9-11). About 332 miles of the corridor is estimated to be underlain by ice-rich permafrost in fine-grained soils, which could cause environmental impacts such as those described in previous sections. An estimated 647 miles of the corridor are exposed to such major mass-movement problems as widespread landsliding on shales, avalanches or rockfalls from steep cliffs, or slides or flows of high river banks at stream crossings. An additional 974 miles of moderate mass-movement hazards include areas of more localized or slower-moving flows and slides. Earthquake hazards along the Fort Yukon Corridor occur primarily within the Richardson Mountains seismic belt, where about 490 miles of the Richards Island Supply Line would potentially be exposed to damaging (magnitude 5.5 and greater) earthquakes. Other potential geologic hazards include stream icings (aufeis) along northern portions of the corridor and floods along most rivers of moderate to high discharge.

Fairbanks Corridor

The Fairbanks Corridor, 2,826 miles in length, follows existing transportation lines for about 87 percent of its length (Table 8.1.2.9-12). It crosses only about 150 miles of wilderness, most of this being in the Mackenzie Delta. It crosses about 450 miles of agricultural lands, mostly within southern Canada. The Fairbanks Corridor follows structural trenches and deeply scoured glacial valleys. It crosses three ranges at low (3,000 to 5,000 feet) altitudes, and farther south, the corridor crosses more rugged terrain of the Canadian Rockies, where five major mountain crossings would be required. Along its entire length, about 300 miles occupy slopes greater than 10 percent. The Fairbanks Corridor crosses about 80 large and 1,049 minor streams and skirts seven large lakes.

The Fairbanks Corridor extends across 270 miles of continuous permafrost and 375 miles of discontinuous permafrost (Table 8.1.2.9-13). About 355 miles of the corridor may be underlain by ice-rich permafrost in fine-grained soils. Zones of potentially severe mass-movements include moderate to steep slopes of deeply entrenched glaciated mountain valleys, and steep river banks at streams crossings. About 700 miles of major and 1,000 miles of moderate mass-movement hazards are anticipated along the corridor. Earthquake hazards occur both within the Richardson Mountains seismic zone and along the Shakwak Trench of southwestern Yukon Territory; a potential hazard of earthquakes of 7.0 magnitude occurs along about 385 miles of the corridor. Other potential geologic hazards include aufeis, floods, glacier surges and outburst floods in the Shakwak Trench, and the slight possibility of volcanism in the Cassiar Mountains.

Table 8.1.2.9-10 Physical setting, Fort Yukon Corridor

Corridor segment	Length (miles)	Miles along existing roads or pipelines	Wilderness areas[1] (miles)	Agricultural areas[2] (miles)	Mountain crossings (elev. in ft)	Stream crossings		Remarks
						Minor[3]	Major[3]	
Alaska border to Watson Lake	517	215	155	0	5,000	213	14	Crosses Stewart River; Simpson Range
Watson Lake to junction with Proposed Route (MP 1265)	685	578	54	140	5,000	230	29	Crosses Peace River; Canadian Rockies
Richards Island Supply Line[4]	490	385	89	0	3,000	162	12	Crosses Main and E. Channels of Mackenzie River; Richardson Mountains
Proposed Route south of MP 1265	840	744	0	302	7,000, 6,500 6,300, 5,900 5,800 (Can. Rockies)	337	16	Crosses Canadian Rockies
Totals	2,532	1,922	298	442	8 crossings >3,000 7 crossings >5,000	942	71	

---

[1] Areas more than 10 miles distant from towns, roads, airfields, and other developments.

[2] Does not include isolated small fields and homesteads.

[3] Drainage basins smaller and larger than 300 mi^2, respectively.

[4] Includes Parsons Lake Lateral Line (15 miles).

Table 8.1.2.9-11 Potential geologic hazard zones, Fort Yukon Corridor

Corridor segment	Length (miles)	Permafrost zones and character (miles)[1]					Slope categories (miles)				Mass-movement zones (est. mi)[2]		Zones of potential earthquake hazard (mi)						Special or unique hazards
		C	D	S	N	IR	<1%	1-10%	10-25%	>25%	Moderate	Major	4.5	5.0	5.5	6.0	6.5	7.0	
Alaska border to Watson Lake	517	0	127	390	0	135	205	247	57	8	200	205	0	0	517	0	0	0	
Watson Lake to junction with Proposed Route (MP 1265)	685	0	0	290	395	25	55	465	157	8	170	175	0	0	685	0	0	0	Mass movements
Richards Island Supply Line[3]	490	270	220	0	0	172	110	345	33	2	185	222	0	0	375	0	0	115	Ice-rich permafrost; seismicity
Proposed Route south of MP 1265	840	0	0	17	823	0	441	331	34	34	419	45	394	0	446	0	0	0	
Totals	2,532	270	347	697	1,218	332	811	1,388	281	52	974	647	394	0	2,023	0	0	115	

[1] C - Continuous permafrost.

D - Discontinuous permafrost.

S - Sporadic permafrost.

N - Permafrost generally absent.

IR - Ice-rich permafrost.

[2] Includes effects of thawing permafrost.

[3] Includes Parsons Lake Lateral Line (15 miles).

Table 8.1.2.9-12 Physical setting, Fairbanks Corridor

Corridor segment	Length (miles)	Miles along existing roads or pipelines	Wilderness areas[1] (miles)	Agricultural areas[2] (miles)	Mountain crossings (elev. in ft)	Stream crossings		Remarks
						Minor[3]	Major[3]	
Alaska border to Watson Lake	530	530	0	0	0	215	15	Crosses Stewart River
Watson Lake to junction with Proposed Route (MP 1265)	685	578	54	140	5,000	230	29	Crosses Peace River and Canadian Rockies
Richards Island Supply Line[4]	771	630	89	0	3,000 3,200	267	20	Crosses East and Main Channels of Mackenzie River, and Richardson and Cassiar Mtns.
Proposed Route south of MP 1265	840	744	0	302	7,000, 6,500 6,300, 5,900 5,800	337	16	Crosses Canadian Rockies
Totals	2,826	2,482	145	442	8 crossings >3,000 6 crossings >5,000	1,049	80	

---

[1] Areas more than 10 miles distant from towns, roads, airfields, and other developments.

[2] Does not include isolated small fields and homesteads.

[3] Drainage basins smaller and larger than 300 mi^2, respectively.

[4] Includes Parsons Lake Lateral Line (15 miles).

Table 8.1.2.9-13 Potential geologic hazard zones, Fairbanks Corridor

Corridor segment	Length (miles)	Permafrost zones and character (miles)[1/]					Slope categories (miles)				Mass-movement zones (est. mi)[2/]		Zones of potential earthquake hazard (mi)						Special or unique hazards
		C	D	S	N	IR	<1%	1-10%	10-25%	>25%	Moderate	Major	4.5	5.0	5.5	6.0	6.5	7.0	
Alaska border to Watson Lake	530	0	115	415	0	75	95	410	21	4	210	195	0	0	260	0	0	270	Alpine mass movements; seismicity
Watson Lake to junction with Proposed Route (MP 1265)	685	0	0	290	395	25	55	465	157	8	170	175	0	0	685	0	0	0	Mass movements
Richards Island Supply Line[3/]	771	270	260	241	0	255	245	485	38	3	245	315	0	0	656	0	0	115	Ice-rich permafrost; seismicity
Proposed Route south of MP 1265	840	0	0	17	823	0	441	331	34	34	419	45	394	0	446	0	0	0	
Totals	2,826	270	375	946	1,235	355	836	1,691	250	49	1,044	730	394	0	2,047	0	0	385	

[1/] C - Continuous permafrost.
D - Discontinuous permafrost.
S - Sporadic permafrost.
N - Permafrost generally absent.
IR - Ice-rich permafrost.

[2/] Includes effects of thawing permafrost.

[3/] Includes Parsons Lake Lateral Line (15 miles).

Haines Option Corridor

The Haines Option Corridor to the Fairbanks Corridor extends 1,156 miles across Canada and an additional 45 miles across the Alaskan Panhandle to the port of Haines (Table 8.1.2.9-14). All but a 90-mile segment in the Mackenzie Delta would follow existing roads or developing transportation corridors. The segments comprising the Haines Option would cross about 90 miles of wilderness and a negligible amount of agricultural lands. They would follow terrain of generally low to moderate relief, with only about 61 miles on slopes steeper than 10 percent (Table 8.1.2.9-15). Mountain crossings would be limited to the low (3,000 feet altitude) Richardson Mountains and to a deeply scoured glacial pass at 3,400 feet altitude across the Coast Mountains of British Columbia. A pipeline constructed along the Haines Option Corridor would cross 458 streams and 29 major rivers with drainage basins greater than 300 square miles.

The Haines Option Corridor would cross an estimated 370 miles of ice-rich permafrost within fine-grained deposits (Table 8.1.2.9-15). Most permafrost hazards would occur along the Richards Island Supply Line, and hence would be identical to those of the Fairbanks Corridor. Earthquake hazards within the Richardson Mountains and the Shakwak Trench also would be identical to those of the Fairbanks Corridor, but the 160-mile segment between Haines and Haines Junction would comprise an additional seismic hazard zone. The 45-mile Alaskan coastal strip between the British Columbia boundary and Haines would be subject to particularly severe seismic hazards, including (1) subaerial and submarine mass movements induced by earthquake vibrations, (2) seiches and tsunamis resulting from fault movements or submarine landslides, and (3) offsets along two active faults that would cross the route. Mass-movement hazards would include (1) potential flows and slides on Pleistocene lake sediments and at river crossings, (2) rockfalls, slides, and avalanches down steep flanks of glacier-carved valleys, and (3) landslides and avalanches generated by tectonism within the Coast Mountains near Haines. As with the Fairbanks Corridor, other potential geologic hazards would include aufeis, floods, and glacier surges as well as outburst floods in the Shakwak Trench.

Wolf Lake Corridor

A summary of some of the more important attributes of the physical setting of the 2,841-mile-long Wolf Lake Corridors (pertinent segments of the proposed route) is given in Table 8.1.2.9-16 and presented here. Of the total distance of the routing, 1,162 miles is along roads or pipelines and 737 miles crosses lands that generally can be considered as wilderness; 538 miles crosses agricultural areas. Relief along the routing is mostly gentle except at crossings of major divides in the Rocky Mountains and at crossings of major streams. The four mountain divides traversed are all 4,000 feet or greater in elevation, the greatest being about 7,000 feet. There are 76 major and 929 minor streams crossed.

The Wolf Lake Corridors cross extensive zones of potential geologic hazards. A summary of the more important characteristics of the hazard zones is given in Table 8.1.2.9-17 and presented here. Of the total length, 1,403 miles cross zones of permafrost classified as continuous or discontinuous and, of this total, 545 miles are estimated to be ice rich. All of these permafrost areas occur north of about 58° N. latitude. Most slopes along the combined route are very low. The exceptions are the moderate to steep slopes of crossings of the Rocky Mountains and crossings of major streams. Of the total length, 2,752 miles have slopes of 10 percent or less, while only 33 miles have slopes of more than 25 percent. (Because of the very wide contour interval of many of the available

Table 8.1.2.9-14 Physical setting, Haines Option Corridor

Corridor segment	Length (miles)	Miles along existing roads or pipelines	Wilderness areas[1] (miles)	Agricultural areas[2] (miles)	Mountain crossings (elev. in ft)	Stream crossings		Remarks
						Minor[3]	Major[3]	
Alaska border to Haines Junction	180	180	0	0	0	114	3	Crosses Donjek River
Richards Island Supply Line to Haines Junction[4]	861	720	89	0	3,000 3,200	290	22	Crosses Yukon River and East and Main Channels of Mackenzie River and Richardson and Cassiar Mountains
Haines Junction to Haines	160	160	2	0	3,400	54	4	Crosses Chilkat River and Coast Mountains
Totals	1,201	1,060	91	0	3 crossings >3,000	458	29	

---

[1] Areas more than 10 miles distant from towns, roads, airfields, and other developments.
[2] Does not include isolated small fields and homesteads.
[3] Drainage basins smaller and larger than 300 mi^2, respectively.
[4] Includes Parsons Lake Lateral Line.

Table 8.1.2.9-15 Potential geologic hazard zones, Haines Option Corridor

Corridor segment	Length (miles)	Permafrost zones and chsracter (miles)[1/]					Slope categories (miles)				Mass-movement zones (est. mi)[2/]		Zones of potential earthquake hazard (mi)						Special or unique hazards
		C	D	S	N	IR	<1%	1-10%	10-25%	>25%	Moderate	Major	4.5	5.0	5.5	6.0	6.5	7.0	
Alaska border to Haines Junction	180	0	115	65	0	50	40	135	2	3	20	130	0	0	0	0	0	180	Alpine mass movements; seismicity; glacier surges and outburst floods
Richsrds Island Supply Line to Haines Junction[3/]	861	270	260	331	0	300	275	545	38	3	245	360	0	0	656	0	0	205	Ice-rich permafrost; seismicity
Haines Junction to Haines	160	0	0	140	20	20	60	85	12	3	70	70	0	0	0	0	0	160	Seismicity; mass movements; tsunamis
Totals	1,201	270	375	536	20	370	375	765	52	9	335	560	0	0	656	0	0	545	

[1/] C - Continuous permafrost.

D - Discontinuous permafrost.

S - Sporadic permafrost.

N - Permafrost generally absent.

IR - Ice-rich permafrost.

[2/] Includes effects of thawing permafrost.

[3/] Includes Parsons Lake Lateral Line (15 mi).

Table 8.1.2.9-16 Physical setting, Wolf Lake Corridors

Corridor segment	Length (miles)	Miles along existing roads or pipelines	Wilderness areas[1] (miles)	Agricultural areas[2] (miles)	Mountain crossings (elev. in ft)	Stream crossings Minor[3]	Stream crossings Major[3]	Remarks
Proposed Route north of Milepost 684	1,013	360	388	0	0	416	23	(See Table 8.1.2.9-2)
Liard River-Wolf Lake Corridor	618	8	349	0	0	177	24	Land mostly undeveloped; many major streams.
Wolf Lake-Emerson Corridor	717	527	0	354	0	186	9	Intensive farming along SE part.
Wolf Lake-Crowsnest Corridor	385	259	0	184	1(4,000)	111	17	Cattle grazing; grain production.
Proposed Route Kingsgate Delivery Line Mileposts 173 to 281	108	108	0	0	3(6,300, 6,500, 7,000)	39	3	(See Table 8.1.2.9-2)
Totals	2,841	1,162	737	538	4(≥ 4,000)	929	76	

[1] Areas more than 10 miles distant from towns, roads, airfields, and other developments.

[2] Does not include isolated small fields and homesteads.

[3] Drainage basins smaller and larger than 300 mi^2, respectively.

Table 8.1.2.9-17 Potential geologic hazard zones, Wolf Lake Corridors

Corridor segment	Length (miles)	Permafrost zones and character (miles)[1]					Slope categories (miles)				Mass-movement zones (est. mi)[2]		Zones of potential earthquake hazard (mi)						Special or unique hazards
		C	D	S	N	IR	<1%	1-10%	10-25%	>25%	Moderate	Major	4.5	5.0	5.5	6.0	6.5	7.0	
Proposed Route north of Milepost 684	1,013	479	534	0	0	525	653	321	23	16	143	858	0	401	196	250	0	166	(See Table 8.1.2.9-3)
Liard River-Wolf Lake Corridor	618	0	390	228	0	20	527	83	5	3	235	31	618	0	0	0	0	0	Mass movements; major stream crossings
Wolf Lake-Emerson Corridor	717	0	0	40	677	0	623	92	1	1	250	27	717	0	0	0	0	0	Mass movements
Wolf Lake-Crowsnest Corridor	385	0	0	50	335	0	296	71	16	2	90	14	365	0	20	0	0	0	Mass movements; expansive clays
Proposed Route-Kingsgate Delivery Line (Mileposts 173-281)	108	0	0	11	97	0	53	33	11	11	14	11	0	0	108	0	0	0	(See Table 8.1.2.9-3)
Totals	2,841	479	924	329	1,109	545	2,152	600	56	33	732	941	1,700	401	324	250	0	166	

[1] C - Continuous permafrost.
D - Discontinuous permafrost.
S - Sporadic permafrost.
N - Permafrost generally absent.
IR - Ice-rich permafrost.

[2] Includes effects of thawing permafrost.

topographic maps, it was not possible to positively identify most of the steep to very steep slopes along the corridors.) Areas along the route that are susceptible to downslope mass movements, including all forms of landslides, are considered in two categories: moderate and major. It is estimated that about 732 miles of the total length traverse geologic materials moderately subject to downslope mass movements, while 941 miles are subject, on a major scale, to such movements. Potentially destructive earthquakes, those of magnitude 6 or greater, might occur along approximately 416 miles. Areas along which the maximum expectable earthquake might be a magnitude 5.5 event constitute approximately 324 miles. Special or unique hazards along the route include: (1) extensive zones subject to mass movements, especially near crossings of the Peace, Wabasca, Athabasca, and North and South Saskatchewan Rivers, where valley sides are steep and geologic materials probably are fine grained; and (2) expansive clays associated with bentonitic shale, and present either as weathered bedrock or as fragments in glacial deposits.

Dome and Brandon Corridors

These corridors serve as alternatives to only the Monchy Delivery Line of the proposed route. Several characteristics of the physical setting of the Dome and Brandon Corridors are summarized in Table 8.1.2.9-18.

Of the total distance of the Dome Corridor, 568 miles are along roads or pipelines. No land can be classed as wilderness. The route crosses 416 miles of agricultural areas, not including rangelands. Relief is mostly very gentle, and no mountain ranges are traversed. Seven major and 133 minor streams are crossed, 4 of the major streams are on the Monchy Delivery Line.

The Brandon Corridor is along roads or pipelines for 769 miles of its distance, and no part of the route can be classed as wilderness. Agricultural areas, not including rangeland, are crossed for 541 miles of the route. Relief is mostly very gentle and no mountain ranges are traversed. Fourteen major streams and 190 minor streams are crossed.

The Dome and Brandon Corridor cross several zones of potential geological hazards. A summary of the characteristics of these zones along both corridors is given in Table 8.1.2.9-19 and presented here. Permafrost is not encountered at the latitudes of these corridors. Along the Dome Corridor, most slopes are very low except where an escarpment or some of the few major streams are crossed. There are 616 miles of slopes along the corridor that are 10 percent or less and only 8 miles of slopes steeper than 25 percent. (However, as described above, not all slopes of that steepness were identified.) Downslope mass movements, including landslides, may be common locally, and two zones are noted, one in which geologic materials may be moderately susceptible to downslope movements and another zone in which there is a major susceptibility to such movements. Along the Dome Corridor, 388 miles of the route are in the moderate zone and 38 miles are in the major zone. The maximum expectable magnitude of earthquakes along the Dome Corridor is probably 5.5. This magnitude level of the earthquake hazard is thought to apply along approximately 115 miles of the route. Special or unique hazards along the Dome Corridor are those of the Monchy Delivery Line segment plus those that are present along the rest of the option. The principal item is the problem of expansive clay associated with bentonitic shale and present either as weathered bedrock or as fragments in glacial deposits.

The Brandon Corridor has slopes that are mostly very low, and only where escarpments or major stream valleys are crossed are some steep slopes

Table 8.1.2.9-18 Physical setting, Dome and Brandon Corridors

Corridor segment	Length (miles)	Miles along existing roads or pipelines	Wilderness areas[1] (miles)	Agricultural areas[2] (miles)	Mountain crossings (elev. in ft)	Stream crossings		Remarks
						Minor[3]	Major[3]	
Dome Corridor								
Proposed route (Monchy) Delivery Line, Mileposts 0 to 234)	234	234	0	141	0	101	4	(See Table 8.1.2.9-2)
Moose Jaw segment	218	186	0	180	0	17	2	Extensive grain production
Dome segment	183	148	0	95	0	15	1	---do---
Totals	635	568	0	416	0	133	7	
Brandon Corridor								
Proposed route (Monchy) Delivery Line, Mileposts 0 to 234)	234	234	0	141	0	101	4	(See Table 8.1.2.9-3)
Moose Jaw segment	218	186	0	180	0	17	2	Extensive grain production
Brandon segment	233	227	0	125	0	37	6	Much grain production
Wolf Lake-Emerson Corridor (Treherne segment)	137	122	0	95	0	35	2	Intensive farming
Totals	822	769	0	541	0	190	14	

[1] Areas more than 10 miles distant from towns, roads, airfields, and other developments.
[2] Does not include isolated small fields and homesteads.
[3] Drainage basins smaller and larger than 300 mi^2, respectively.

Table 8.1.2.9-19 Potential geologic hazard zones, Dome and Brandon Corridors

Corridor segment	Length (miles)	Permafrost zones and character (miles)[1]					Slope categories (miles)				Mass-movement zones (est. mi)		Zones of potential earthquake hazard (mi)						Special or unique hazards
		C	D	S	N	IR	<1%	1-10%	10-25%	>25%	Moderate	Major	4.5	5.0	5.5	6.0	6.5	7.0	
Dome Corridor																			
Proposed Route (Monchy Delivery Line, Mileposts 0-234)	234	0	0	0	234	0	119	97	10	8	175	16	234	0	0	0	0	0	(See Table 8.1.2.9-3)
Mooae Jaw segment	218	0	0	0	218	0	164	53	1	0	120	13	208	0	10	0	0	0	Expansive clays
Dome segment	183	0	0	0	183	0	127	56	0	0	93	9	78	0	105	0	0	0	Some expansive clay
Totals	635	0	0	0	635	0	410	206	11	8	388	38	520	0	115	0	0	0	
Brandon Corridor																			
Proposed route (Monchy Delivery Line, Mileposts 0-234)	234	0	0	0	234	0	119	97	10	8	175	16	234	0	0	0	0	0	(See Table 8.1.2.9-3)
Moose Jaw segment	218	0	0	0	218	0	164	53	1	0	120	13	208	0	10	0	0	0	Expansive clays
Brandon segment	233	0	0	0	233	0	210	20	2	1	35	5	148	0	85	0	0	0	Some mass movements
Wolf Lake-Emerson Corridor (Treherne segment)	137	0	0	0	137	0	96	41	0	0	114	11	137	0	0	0	0	0	---do-------------
Totals	822	0	0	0	822	0	589	211	13	9	444	45	727	0	95	0	0	0	

[1] C - Continuous permafrost.
D - Discontinuous permafrost.
S - Sporadic permafrost.
N - Permafrost generally absent.
IR - Ice-rich permafrost.

encountered. Slopes of 10 percent or less are crossed for 800 miles of the Brandon Corridor and only 9 miles of the route cross slopes steeper than 25 percent. Downslope mass movements of geologic materials can be considered as possibly a major hazard along 45 miles of the Brandon Corridor and as a moderate hazard along 444 miles of the route. Earthquakes having a maximum expectable magnitude of 5.5 are possible along the option; this degree of earthquake hazard is thought to apply along approximately 95 miles of the route. Special or unique hazards characteristic of the Brandon Corridor are those of the Monchy Delivery Line, in addition to the special problems present along the other elements of the option. Of major importance are the expansive clays associated with bentonitic shale.

Mineral Resources

None of the routes or corridors discussed above would have any major impact on known metallic mineral resources. Most of these resources could be recovered by underground methods that would not conflict with surface land uses such as those involved in pipeline construction and operation. Portions of the old Klondike placer fields near Dawson, Y.T., might be affected by the approval of a pipeline in the Fort Yukon Corridor, which would require exclusive dedication of surface rights for the life of the project and would therefore preclude all surface mining from the 120-foot-wide right-of-way.

Large quantities of sand, gravel, and stone would be required for fill, roadways, pad foundations and other purposes if a pipeline were to be built along any of the routes or corridors. In most modes of pipeline construction, consumptive use of these construction materials would be greatest per line mile within the continuous permafrost zone, progressively less within the discontinuous zone and its southern fringe, and least south of the permafrost limit (see Tables 8.1.2.9-2 through 8.1.2.9-19). The Applicant's proposed use of snow and ice roads during the construction phase might modify this relationship however. Rate of consumption of sand, gravel, and stone per line mile also would be affected by presence or absence of preexisting highways or haul roads (see Tables 8.1.2.9-2 through 8.1.2.9-19). Wilderness areas without road access would require construction of haul roads as well as pipelines. Although construction materials are available in adequate amounts along all alternative routes and corridors, in some areas their utilization would entail longer hauls from borrow pits and greater attendant disruption of the total environment than would be the case elsewhere. In some areas use of construction materials for the project could so deplete regional resources as to render infeasible other unrelated construction projects. Particularly serious problems would occur within the Alberta Plateaus of southwestern Canada and perhaps the Eagle Plain of northern Yukon Territory.

Approval of any corridor would involve exclusive dedication of surface rights for the life of the project and would therefore preclude all strip mining of coal within the 120-foot-wide pipeline right-of-way. This could have a significant impact only in the Bow River area west of Calgary and in the Crowsnest Pass Coalfield on the Alberta-British Columbia border where these areas would be crossed by the Kingsgate Delivery Line.

The potential for future discoveries of oil and gas is greatest along segments of the proposed route near the Arctic Coast and the Mackenzie Delta and in the Tathlina sedimentary province of the southern District of Mackenzie. Construction of a pipeline along the proposed route would have the impact of greatly stimulating exploration in the promising areas through which it passed. The Babbage Bight Corridor, like the proposed route, would cross areas of high oil and gas potential along the Arctic Coast and the

Mackenzie Delta. The Interior Route is more remote from the promising areas along the Arctic Coast and thus would provide less stimulus to future exploration and discovery. The Fort Yukon, Fairbanks, and Haines Corridors all pass through relatively unpromising areas and would provide minimal stimulation to exploration and new discoveries.

Water Resources

The various impacts on water resources would be similar along all the routes and corridors, but the total impact would vary directly with the number of stream crossings on the different routes (Tables 8.1.2.9-2 through 8.1.2.9-19). Construction of the pipeline would alter the surface and ground-water environment. The degree of potential impact would depend upon the design and measures taken during construction to minimize the impact. Four areas of concern are: (1) drainage disruption and channel erosion, (2) icings, (3) water quality, and (4) effects on ground water.

Drainage disruption due to construction of roads and airstrips and the obstruction of surface and subsurface water flow by the chilled pipe could lead to local flooding, icings, and accelerated erosion with subsequent damage to the pipe.

Icings caused by disturbance of the active zone during and following construction could lead to local flooding, damage to terrain and vegetation, ice jams, bank erosion and changes of stream flow.

Water quality would be subjected to alteration during construction by the addition of organic material, petroleum products, waste discharge and backfill. Such alterations would increase suspended sediment, deplete oxygen in the water and could lead to pollution of streams and the killing of fish and other contained organisms.

Ground-water flow would be altered by construction activities through compression of the active layer, destruction of vegetation and actual physical blockage because of the presence of the pipe and its attendant frozen soil bulb. Resultant impacts would likely be icings, thermokarsts, slope failures, and possible frost heaves.

A summary table of impacts is presented in Table 3.1.2.5-2.

Vegetation

Vegetation is abundant throughout all routes and corridors, and all known plant communities are so extensive and repetitive that none can be considered to be threatened by the particular pipeline. The 400-mile strip of Herbaceous Coastal Tundra that would be crossed by the proposed route, the Cross-Delta Route and the Babbage Bight Corridor would be relatively vulnerable owing to its limited area, high ice content, susceptibility to thermal degradation and erosion, and slow recovery rate following disturbance.

The Interior Route would cross mountains farther inland, and vegetation of alpine tundra types would probably be less sensitive to disruption. However, fires could have a serious impact where the Interior Route would cross the winter range of caribou in the Forest-Tundra. Fire damage to the abundant lichens, which are slow to recover following fire, could have serious secondary effects by destroying the winter food supply of caribou.

The Fairbanks and Fort Yukon Corridors possess the same vegetation types as the proposed route, excepting Herbaceous Coastal Tundra, and would include extensive areas of Alpine Tundra, as in the case of the Interior Route. Both corridors cross unglaciated areas where rare and endemic species of plants occur and could be endangered by corridor activities.

The Haines Option Corridor to the Fairbanks Corridor would cross Alpine Tundra and Boreal Forest communities in British Columbia and Pacific Coastal Forest in Alaska. It would follow an established transportation line (the Haines Road) through these vegetation types, and major environmental impacts are unlikely.

Wildlife

Impacts on wildlife would be greatest in the relatively undeveloped and wilderness areas of northwestern Canada and least along Southern Canada portions of the routes and corridors. Differences among these routes and corridors also are greatest in northwestern Canada, where they are most widely separated and cross the most diverse terrain.

Fish

The greatest threats to fish populations along streams would arise from increased siltation and obstruction to their movements. Both would be related to the magnitude of cut-grading operations, number of stream crossings (Tables 8.1.2.9-2 through -19), number of culvert installations, and the nature of the pipeline alignment (whether transverse or parallel to streams).

Along the proposed and Cross-Delta routes, siltation problems would be amenable to control and should have adverse effects on fish for only a few years. However, spilled fuel or other toxic chemicals could reach streams draining into the Mackenzie River and the Beaufort Sea, threatening the aquatic systems of these regions.

Along the Interior Route, erosion and stream siltation could result from construction activities along valley sides. Sediment influx into stream systems could be a threat to fish populations for a number of years.

The large number of stream crossings, as well as the great total distance along which the pipeline would parallel streams, would create severe siltation problems along the Fort Yukon and Fairbanks Corridors. The Fort Yukon Corridor would be especially critical since it crosses large areas of wilderness. The permanent and temporary roads that would be built for pipeline construction would further add to siltation problems.

A pipeline along the short land segment of the Babbage Bight Corridor would entail risks to fish from toxic chemicals entering the Mackenzie River or the Beaufort Sea. The Haines Option Corridor could have adverse effects on fish populations of the Chilkat River system and Chilkat Inlet. Additional impacts such as thermal pollution or spillage of toxic chemicals might result from operation of LNG plants at either Babbage Bight or Haines.

Mammals

The proposed and Cross-Delta routes would cross areas rich in such species as caribou, moose, grizzly bear, and aquatic fur-bearers. These routes would cross important calving grounds of the Porcupine caribou herd and come within a mile of Dall sheep range in the Richardson Mountains. Winter construction would avoid interference with caribou calving, but subsequent aircraft and compressor-station noise could be a problem. Disturbance during both construction and operation could be critical to Dall sheep.

The Interior Route would cross the spring migration path of caribou moving from winter range to calving grounds and summer grazing in the tundra. Its use would also entail increased contact with moose and grizzly bear, and potential disturbance of bear denning sites.

Use of the Fort Yukon and Fairbanks Corridors would generally affect the same species of mammals as the proposed route. Both corridors follow or closely parallel existing transportation lines for much of their length, and the wildlife of these areas has already been subjected to human disturbance. The Fort Yukon Corridor would intrude on extensive wilderness areas, however.

The Babbage Bight Corridor and Cross-Delta Route would affect mammals of the Beaufort Sea coast and Mackenzie Delta, as described for the proposed route. In addition, seals, walrus, beluga whales, and polar bear would be affected by barge traffic and spills of fuel and other toxic materials. The Haines Option Corridor probably would have little adverse effect on terrestrial mammals, owing to the presently developed state of the corridor and the terminal area. Greater impacts on marine mammals might result from emission of pollutants into Chilkat Inlet.

Birds

The impact of the proposed and Cross-Delta routes would be greatest for the Yukon Coast and the Mackenzie Delta, which comprise some of the most productive bird habitat in North America. Farther to the south, this route follows the Mackenzie Valley, a major flyway for migrating birds. Islands along the Mackenzie River and the shores of large lakes provide the only available open water in May for the resting, feeding and mating functions of migrating waterfowl. Shorebirds and waterfowl use the riverine habitats for nesting, molting and brood-rearing and for feeding and nesting during autumn migration. All project components which would interfere with feeding, nesting, molting and staging of these largely migratory species would have serious consequences on an international resource. Among the principal impacts would be disturbance of birds by aircraft. Snow geese are especially susceptible to aircraft disturbance.

The Interior Route from the Alaska-Yukon border to Fort McPherson would have potential impacts on raptorial species and on waterfowl. Peregrine falcons, gyrfalcons, and golden eagles nest at many sites along the Interior Route, and peregrine falcons and bald eagles nest along the Porcupine River. The Old Crow Flats is second only to the Mackenzie Delta as a critical waterfowl-production area in northwestern Canada. This area has an annual breeding population of thousands of ducks, and many thousands of geese use this habitat during migration in spring and autumn.

Habitat change through drainage disruption along the Fort Yukon and Fairbanks Corridors would be a minor to moderate impact owing to the mountain crossings and the general absence of marshy terrain. The Fort Yukon Corridor crosses extensive areas of wilderness and even larger tracts of near-wilderness quality. All bird populations would be subject to disturbance in some degree, but raptorial species probably would be the most significantly affected everywhere south of Fort McPherson.

Construction and operation of a pipeline along the Babbage Bight Corridor and Cross-Delta Route would have great potential impact on shore and offshore birds and bird habitat along the Beaufort Sea coast and Mackenzie Delta. A pipeline along the Haines Option Corridor would have much less impact owing to the relatively developed state of this area. The potential impact on birds of LNG plants at Babbage Bight or Haines is unknown.

Archeology

All of the areas of northern Canada traversed by the different routes and corridors probably contain important archeologic sites. From their point of origin, the proposed route, Cross-Delta Route, and Babbage Bight Corridor would follow the Arctic coast through extensive areas utilized intensively by prehistoric and early historic Eskimo groups. The Interior Route would extend farther inland and, except for the Old Crow Basin, would cross terrain less heavily utilized by prehistoric hunters. Within the Mackenzie Valley, however, the proposed, Interior, and Cross-Delta routes would follow a probably major migration route for early men. The Fairbanks and Fort Yukon Corridors are archeologically significant because both cross extensive unglaciated areas where prehistoric sites of late Pleistocene age are likely to occur.

Assuming that many of the archeologic sites along highways have been excavated by archeologists or looted by collectors, the greatest single factor controlling archeological impact of a pipeline is likely to be the length of inaccessible wilderness that it crosses. According to this criterion, the proposed route, Cross-Delta Route, Interior Route, and Fort Yukon Corridor are likely to have great potential impacts on archeological sites. The relatively accessible Fairbanks Corridor and Haines Option and the short Babbage Bight Corridor would have moderate impact.

Social and Economic Factors

In northwestern Canada, the social and economic impacts of any pipeline would be relatively great and also would differ significantly between the different corridors and routes. Many characteristics of life style, community structure, educational background, ethnic group distribution and economic structure are unique to the several routes and corridors, and these would be paramount in determining the impact of the respective project. Across southern Canada, the social and economic impacts of pipeline construction and operation would probably be relatively small, but the potential economic stimulus could be significant in some areas. Conditions in the rural and urban areas through this region would generally be very similar, and therefore the overall impacts should be essentially equal.

The Interior and Cross-Delta Routes would have nearly the same socioeconomic impacts. These routes, particularly north of 60° N latitude, would pass through regions in which the scattered groups of Native peoples have had limited contact with wage economy, modern urbanized housing and community infrastructure, modern transportation networks and related facilities, and the kind of social, educational and governmental structures that are typical of predominantly Caucasian societies. A partial transition has been made to a wage economy, but in varying degrees the people are still dependent on the traditional land-based subsistence economy and life. The short-range social and related economic impacts, both good and bad, of the proposed pipeline would be relatively great among these Native communities.

The Fort Yukon and Fairbanks Corridors would be subject to less severe social and economic impacts during construction and operational phases of a pipeline. The populations of the regions that are traversed by these two corridors have been part of a wage economy for many years, and the regional development and infrastructure have been based on mineral exploration and mining, tourism and allied recreational activities, and military and civilian government activities. In the region south of Watson Lake, oil and gas exploration and development as well as agricultural activities are a significant part of the life and economy. Communities along these routes are small, except for Whitehorse, but local government and service functions are similar to those of communities in southern Canada, and modern-style buildings are the rule. The Native residents are generally adapted to this type of socioeconomic lifestyle, and there is little reliance on a land-based subsistence economy.

The social and related economic impacts of the Babbage Bight Corridor would be essentially limited to the Mackenzie Delta region, and would probably affect the communities of Tuktoyaktuk, Inuvik, and Aklavik. The establishment of a new community and industrial facilities at Babbage Bight could afford the opportunity to create a modern, small urban center that would have a substantial socioeconomic impact. Such a new community might induce people to emigrate from the other communities in this region or from farther inland, resulting in a detrimental impact on the social and economic structure of the decimated communities. The wage-oriented socioeconomic activities associated with development of the Babbage Bight Corridor would be likely to remove the Native people almost entirely from a land-related hunting-fishing-trapping economy, except on a limited recreational basis.

The socioeconomic impact of the Haines Option Corridor would be comparable to that of portions of the Fairbanks Corridor north and west of Whitehorse with the addition of a 160-mile segment southward from Haines Junction. This segment would follow a long-established transportation route and would terminate in a community with a modern economic base. Community growth would inevitably follow establishment of LNG terminal facilities at Haines, but impact would not be likely to affect the Canadian portion of this alternative Corridor.

Inasmuch as the Interior and Cross-Delta Routes would pass through regions of gas and oil potential, a secondary long-term impact from activities induced by the presence of pipeline might be anticipated. The segments of the Fort Yukon and Fairbanks Corridors and the Haines Option Corridor which pass through southern Yukon Territory would not be expected to generate secondary impacts of this type owing to the probable absence of oil and gas fields in this region.

Recreation

Use of the proposed route, Cross-Delta Route, or the Babbage Bight Corridor would be destructive to wilderness and esthetic values of the Arctic Coast, and hence damaging to recreation resources. The Babbage Bight Corridor would have an additional impact owing to the necessity for an LNG plant and permanent townsite with related service and transportation facilities. South from the Mackenzie Delta, the proposed and Cross-Delta routes would follow existing or developing transportation lines for most of their length. Impact on recreation through this stretch would include disturbance of roadside scenery and camping facilities.

The Interior Route would cross extensive wilderness areas before joining the proposed route near Fort McPherson, N.W.T. South of Fort McPherson, its impacts would be identical to those of the proposed route.

The Fairbanks and Fort Yukon Corridors both pass through or close to three Provincial parks in British Columbia, and the Fairbanks Corridor also skirts the proposed Kluane National Park. The Fairbanks Corridor follows existing or planned roads for almost its entire length, thus having potential significant impact on such recreational features as scenery and roadside camping facilities. Construction in the Fort Yukon Corridor would disturb extensive roadless wilderness areas, whereas use of the Fairbanks Corridor would have very little effect on wilderness. Within southern Canada, the routes and corridors would probably have little or no impact on recreation and esthetic resources.

REFERENCES

Alaskan Arctic Gas Pipeline Company, 1974, Environmental Report of Alaskan Arctic Gas Pipeline Company (Chapter V): Batt Bates & Co., Washington, D. C., unpaged.

Alaskan Arctic Gas Pipeline Co., 1975a, Comments of Alaskan Arctic Gas Pipeline Company Relative to Part II (Canada) of the Draft Environmental Impact Statement of the Department of the Interior Regarding the Alaska Natural Gas Transportation System, Appendix A, October 28.

Alaskan Arctic Gas Pipeline Co., 1975b, Comments of Alaskan Arctic Gas Pipeline Company Relative to Part II (Alaska) of the Draft Environmental Impact Statement of the Department of the Interior Regarding the Alaska Natural Gas Transportation System, October 28.

Bostock, H. S., 1936, Carmacks Sheet, Yukon Territory: Canada Geol. Survey Map 340A.

____ 1942, Ogilvie, Yukon Territory: Canada Geol. Survey Map 711A.

_____ 1948, Physiography of the Canadian Cordillera, with special reference to the area north of the fifty-fifth parallel: Canada Geol. Survey Mem. 247, 106 p.

______ 1957, Yukon Territory: Canada Geol. Survey Mem. 284, 650 pp.

_____ 1964, Geology, McQuesten, Yukon Territory: Canada Geol. Survey Map 1143A.

______ 1970, Physiographic subdivisions of Canada, p. 9-30 in Douglas, R. J. W. (ed.), Geology and economic minerals of Canada: Canada Geol. Survey Econ. Geol., Rept. 1; 838 pp.

Bostock, H. W., and Lees, E. J., 1938, Laberge map-area, Yukon: Canada Geol. Survey Mem. 217, 32 pp.

Brandon, L. W., 1965, Ground water hydrology and water supply in the District of Mackenzie, Yukon Territory, and adjoining parts of British Columbia: Canada Geol. Survey Paper 64-39, 102 pp.

Brown, R. J. E., 1967, Permafrost in Canada: Canada Geol. Survey Map 1246A.

Brunskill, G. J., Rosenberg, D. M., Snow, N. B., Vascotto, G. L., and Wageman, R., 1973a, Ecological studies of aquatic systems in the Mackenzie-Porcupine drainages in relation to proposed pipeline and highway developments: Environmental-Social Comm. Northern Pipelines, Task Force on Northern Oil Devel. Rept. 73-40 (v. 1), Info. Canada Cat. no. R72-10073/1-1, 131 pp.

______1973b, Ecological studies of aquatic systems in the Mackenzie-Porcupine drainages in relation to proposed pipeline and highway developments, Volume II, Appendixes: Environmental-Social Comm. Northern Pipelines, Task Force on Northern Oil Devel. Rept. 73-41 (v. 2), Info. Canada Cat. no. R72-10073/1-2, 345 p.

Bryan, J. E., 1973, The influence of pipeline development on freshwater fishery resources of northern Yukon Territory, aspects of research conducted in 1971 and 1972: Environmental-Social Comm. Northern Pipelines, Task Force on Northern Oil Devel. Rept. 73-6, Info. Canada Cat. No. R72-9773, 63 pp.

Campbell, R. B., 1967, Geology of the Glenlyon Map-area, Yukon Territory: Canada Geol. Survey Mem. 352, 92 pp.

Campbell, R. B., and Wheeler, J. O., 1960, Geology, Glenlyon, Yukon Territory: Canada Geol. Survey Map 13-1961, Preliminary Series.

Canada Geol. Survey, 1963, Geology, northern Yukon Territory and northwestern District of Mackenzie 1:1,000,000: Canada Geol. Survey Map 10-1963.

______ 1969, Geological map of Canada: Canada Geol. Survey Map. 1250 A, 1 sheet, scale 1:5,000,000.

Canadian Arctic Gas Pipeline Limited, 1974a, Summary of projected gas volumes by years (Section 8.b.1.1): An exhibit in support of applications to the Department of Indian Affairs and Northern Development of Canada for authorization to use land and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, unpaginated.

Canadian Arctic Gas Pipeline Limited, 1974b, Cost of facilities (section 10): exhibits in support of an application to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, sections individually paginated.

Canadian Arctic Gas Pipeline Limited, 1974c, Environmental statement (Canada - north of the 60th parallel), Section 14.d N: An exhibit in support of applications to the Department of Indian Affairs and Northern Development of the Government of Canada for authorization to use land and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, unpaged.

Canadian Arctic Gas Pipeline Limited, 1974d, Environmental statement (Canada - south of the 60th parallel), Section 14.d S: An exhibit in support of applications to the Department of Indian Affairs and Northern Development of the Government of Canada for authorization to use land and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, unpaged.

Canadian Arctic Gas Pipeline Limited, 1974e, Alternative corridors and systems of transportation, Section 14.e: An exhibit in support of applications to the Department of Indian Affairs and Northern Development of the Government of Canada for authorization to use land

and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, unpaged.

Canadian Arctic Gas Pipeline Limited, 1975a, Alternative cross-delta routing: alignment sheets (section 8.a.3), design drawings-delta crossings (section 8.b.3, flow diagrams (section 8.b.4): An exhibit in support of applications to the Department of Indian Affairs and Northern Development of the Government of Canada for authorization to use land and to the National Energy Board of Canada for a certificate of public convenience and necessity authorizing the construction of pipeline facilities, sections individually paginated.

Canadian Arctic Gas Pipeline Limited, 1975b, Location of facilities (section 8.a), design and capacity of facilities (section 8.b), cost of facilities (section 10), pro-forma financial statements (section 11), construction plan (section 13.a), operations and maintenance plans (section 13.b), environmental statement (section 14.d): Supplement to applications and exhibits relative to alternate 42" supply lateral line size; individually paginated.

Charron, J. E., 1961, Ground-water resources of Plum Coulee area, Manitoba (62H/SW and 62G/SE (parts of)): Canada Geol. Survey Paper 60-22, 81 pp., map, scale 1:126, 720.

Cinq-Mars, Jacques, 1973, Preliminary archaeological study, Mackenzie Corridor: Environmental-Social Comm., Northern Pipelines, Task Force on Northern Oil Development, Rept. No. 73-10, Inf. Canada Cat. No. R72-8273, IAND Pub. No. OS-1 506-000-EE-A1, 60 p. and 7 appendices.

Craig, D. B., and Laporte, P., 1972, Mineral industry report 1969 and 1970, Volume 1 Yukon Territory and southwestern sector District of Mackenzie: Northern Economic Development Branch, Dept. of Indian Affairs and Northern Development, Government of Canada, 188 pp.

Davies, K. F., 1974, Hydrometric data summary, Mackenzie River basin, 1973: Environmental-Social Comm. Northern Pipelines, Task Force on Northern Oil Devel. Rept. 74-8, Info. Canada Cat. no. R57-6/1973, 84 pp.

Denton, G. H., 1974, Quaternary glaciations of the White River Valley, Alaska, with a regional synthesis for the northern St. Elias Mountains, Alaska, and Yukon Territory: Geol. Soc. America Bull., v. 85, no. 6, pp. 871-92.

Dominion Bureau of Statistics, 1953, Canada 1953: 320 pp.

Douglas, R. J. W. (ed.), 1970, Geology and economic minerals of Canada: Canada Geol. Survey Econ. Geology Rept. 1, 838 p.

Eakin, H. M., 1919, The Porcupine gold placer district, Alaska: U.S. Geol. Survey Bull. 699, 29 p.

Elson, J. A., 1960, Surficial geology, Brandon, Manitoba (62G), in Halstead, E. C., 1959 (1960), Ground-water resources of the Brandon map-area, Manitoba: Canada Geol. Survey Mem. 300, 67 p., map 1067A, scale 1:253,440.

Environment Protection Board, 1974, Environmental impact assessment of the portion of the Mackenzie gas pipeline from Alaska to Alberta: (4 volumes).

Fremlin, G. (Ed.) 1974, The National Atlas of Canada, The Macmillan Company of Canada Limited, Toronto, 254 p.

Fyles, J. G., Heginbottom, J. A., and Rampton, V. N., 1972, Quaternary geology and geomorphology, Mackenzie Delta to Hudson Bay: Guidebook, Field Excursion A30, 24th Internatl. Geol. Congr., Montreal, 23 pp.

Gabrielse, H., 1957, Geological reconnaissance in the northern Richardson Mountains, Yukon and Northwest Territories: Canada Geol. Survey Paper 56-6, 11 pp.

______ 1961, Geology, Rabbit River, British Columbia: Canada Geol. Survey Map 2-1961, Preliminary Series.

______ 1963, Geology, Rabbit River, British Columbia: Canada Geol. Survey Map 46-1962, Preliminary Series.

______ 1967, Geology, Watson Lake, Yukon Territory: Canada Geol. Survey Map 19-1966, Preliminary Series.

______ 1969, Geology of Jennings River map-area, British Columbia (104-0): Canada Geol. Survey Paper 68-55, 37 pp.

Gabrielse, H., and Blusson, S. L., 1969, Geology of the Coal River Map-area, Yukon Territory and District of Mackenzie: Canada Geol. Survey Paper 68-38, 22 pp.

Gill, Don, 1973, A spatial correlation between plant distribution and unfrozen ground within a region of discontinuous permafrost, p. 105-113, in Permafrost - North American Contribution, 2nd International Conf. Yakutsk, 1973: Washington, D.C., Nat. Acad. Sci., 783 pp.

Government of Alberta, 1969, Atlas of Alberta: Edmonton, Alberta Univ. Press, 162 pp.

Green, L. H., 1972, Geology of Nash Creek, Larsen Creek, and Dawson map-areas, Yukon Territory: Canada Geol. Survey Mem. 364, 157 pp.

Griffiths, W., Sekerak, K., and Jones, A., 1974, Distribution of fish species along alternate gas pipeline corridors in Alaska, the Yukon Territory and Northwest Territories, Arctic Gas Biological Report series, vol. 17.

Hernandez, H., 1974, Possible effects on vegetation of the proposed gas pipeline from Prudhoe Bay, Alaska, and the Mackenzie Delta to Alberta: in Research Reports, Environmental impact assessment of the portion of the Mackenzie gas pipeline from Alaska to Alberta, v. IV, pp. 37-68: Environment Protection Board, Winnipeg.

Hughes, O. L., 1969, Distribution of open-system pingos in central Yukon Territory with respect to glacial limits: Canada Geol. Survey Paper 69-34, 8 pp.

______ 1970, Incidental observations on Quarternary crustal movements, central Yukon Territory: Canadian Jour. Earth Sciences, v. 7, p. 569.

Hughes, O. L., Campbell, R. B., Muller, J. E., and Wheeler, J. O., 1969, Glacial limits and flow patterns, Yukon Territory, south of 65 degrees north latitude: Canada Geol. Survey Paper 68-34, 9 pp.

Hughes, O. L., Rampton, V. N., and Rutter, N. W., 1972, Quaternary geology and geomorphology, southern and central Yukon (northern Canada): Guidebook, Field Excursion A1, 24th Internat. Geol. Congr., Montreal, 59 pp.

Hume, G. S., 1954, The lower Mackenzie River area, Northwest Territories and Yukon: Canada Geol. Survey Mem. 273, 118 pp.

Irish, E. J. W., 1958, Charlie Lake, west of sixth meridian, British Columbia: Canada Geol. Survey Map 17-1958, Preliminary series.

______ 1970, Halfway River map-area, British Columbia: Canada Geol. Survey Paper 69-11, 154 pp.

Irving, W. N., and Harington, C. R., 1973, Upper Pleistocene radiocarbon-dated artifacts from the northern Yukon: Science, v. 179, no. 4071, pp. 335-340.

Johnston, W. A., Wickenden, R. T. D., and Weir, J. D., 1948, Preliminary map, surface deposits, southern Saskatchewan: Canada Geol. Survey Paper 48-18, 2 sheets, scale 1:380,160.

Kathol, C. P., and McPherson, R. A., 1974, Susceptibility of geologic deposits to erosion in the House Mountain area. Alberta: Alberta Resource Rept. 74-5, 33 pp.

Kelley, C. C., and Sprout, P. N., 1956, Soil survey of the Upper Kootenay and Elk River valleys in the East Kootenay District of British Columbia Dept. Agriculture Soil Survey Report no. 5, 99p.

Kindle, E. D., 1953, Dezadeash map-area, Yukon Territory: Canada Geol. Survey Mem. 268, 68 pp.

Klassen, R. W., 1966, Surficial geology, Riding Mtn., Manitoba-Saskatchewan (62K): Canada Geol. Survey Map 16-1965, scale 1:253,440.

Krinsley, D. B., Davies, W. E., Rachlin, J., and Newton, E. G., 1971, Existing environment of natural corridors from Prudhoe Bay, Alaska, to Edmonton, Canada: U. S. Geol. Survey open-file rept. 502, 103 pp.

Kunst, H., 1973, The Peel Plateau; in McCrossen, R. C. (ed.), The future petroleum provinces of Canada, pp. 245-273: Calgary, Can. Soc. Petroleum Geologists, 720 pp.

Leblanc, G., and Wetmiller, R. J., 1974, An evaluation of seismological data available for the Yukon Territory and the Mackenzie Valley: Canadian Jour. Earth Sci., v. 11, pp. 1435-1454.

Lemke, R. W., and Yehle, L. A., 1972, Reconnaissance engineering geology of the Haines area, Alaska, with emphasis on evaluation of earthquake and other geologic hazards: U. S. Geol. Survey open-file rept. 515, 109 pp.

Lewis, C.P., 1975, Sediments and sedimentary processes, Yukon-Beaufort Sea coast: Geol. Survey Canada Paper 75-1, Part. B, p. 165-170.

Lindsay, J. D., Heringa, P. K., Pawluk, S., and Odynsky, W., 1957, Exploratory soil survey of Alberta: Map Sheets 84-C (east half), 84-B, 84-A, and 74-D: Alberta Research Council Prelim. Soil Survey Rept. 58-1, 32 pp.

Linell, K. A., 1973, Long-term effects of vegetative cover on permafrost stability in an area of discontinuous Permafrost, pp. 688-693 in Permafrost North American Contrib. 2d Int. Conf. Yakutsk, U.S.S.R: Washington, D. C. Natl. Acad. Sci., 783 pp.

Little, H. W., Belyea, H. R., Stott, D. F., Latour, B. A., and Douglas, R. J. W., 1970, Economic minerals of western Canada, in Douglas, R.J.W. (ed.), Geology and economic minerals of Canada: Canada Geol. Survey Econ. Geology Rept. 1, ch. 9, pp. 490-546.

Lord, C. S., 1944, Geological reconnaissance along the Alaska Highway between Watson Lake and Teslin River, Yukon and British Columbia: Canada Geol. Survey Paper 44-25, 20 pp.

Mackay, J. R., 1963, The Mackenzie Delta area, N. W. T.: Dept. Mines and Tech. Surveys, Geog. Branch, Mem. 8, 202 pp.

______ 1967, Permafrost depths, lower Mackenzie Valley, Northwest Territories: Arctic, v. 20, no. 1, pp. 21-26.

MacKevett, E. M., Jr., Robertson, E. C., and Winkler, G. R., 1974, Geology of Skagway B-3 and B-4 quadrangles, southeastern Alaska: U. S. Geol. Survey Prof. Paper 832, 33 pp.

Martin, H. L., 1973, Eagle Plain Basin, Yukon Territory; in McCrossen, R. C. (ed.), The future petroleum provinces of Canada, pp. 275-306: Calgary, Can. Soc. Petroleum Geologists Mem. 1, 720 pp.

McAully, R. S., 1973, Magnitude of floods - Yukon Territory: Water Survey of Canada, Planning and Studies Sec., 38 pp.

McCart, P. J., 1974, Late winter surveys in lakes and streams in Canada and Alaska along the gas pipeline route under consideration by Canadian Arctic Gas Study Ltd., 1972-73, Chapp. 1, in McCart, P. J., (ed.), Fisheries research associated with proposed gas pipeline route in Alaska, Yukon and Northwest Territories: Arctic Gas Biological Rept. Ser. V. 15, Canadian Arctic Gas Study Ltd. and Alaskan Arctic Gas Study Co., 183 pp.

McCourt, K.H.; Feist, J.D.; Doll, D.; Russell, J.J. 1974. Disturbance Studies of Caribou and Other Mammals in the Yukon and Alaska, 1972, Arctic Gas Biological Report Series, Vol. 5, Canadian Arctic Gas Study, Ltd. and Alaskan Arctic Gas Study Co.

McCrossan, R. G., and Porter, J. W., 1973, The geology and petroleum potential of the Canadian sedimentary basins-a synthesis, pp. 589-720, in McCrossan, R. G. (ed.), Future Petroleum Province of Canada: Canadian Soc. Petroleum Geologists Mem. 1, 720 pp.

Meyboom, P., 1967, Interior plains hydrogeological region, Chapp. 6, in Brown, I. C., (ed.), Ground-water in Canada: Canada Geol. Survey, Economic Geology Rept. 24, pp. 131-158.

Millar, J. F. V., 1974, Proposal for Archeological salvage, pipeline corridor, Yukon and Northwest Territories: Archaeol. Suppp. to Canadian Arctic Gas Biol. Rept. Ser., 42 pp.

Muller, J. E., 1967, Kluane Lake map-area, Yukon Territory: Canada Geol. Survey Mem. 340, 137 pp.

Mulligan, Robert, 1963, Geology of Teslin map-area, Yukon Territory (105C): Canada Geol. Survey Mem. 326, 96 pp.

Pelletier, B. R., 1959, Geology, Tetsa River, Peace River District, British Columbia: Canada Geol. Survey Map 29-1959, Preliminary series.

Pelletier, B. R., and Stott, D. F., 1963, Trutch map-area, British Columbia: Canada Geol. Survey Paper 63-10, 12 pp.

Pihlainen, J. A., et al., 1956, Soils in some areas of the Mackenzie Delta region: Div. Building Research, National Research Council, Ottawa, Tech. Paper No. 43, 26 pp.

Poole, W. H., Roddick, J. A., and Green, L. H., 1960, Geology, Wolf Lake, Yukon Territory: Canada Geol. Survey Map 10-1960, Preliminary series.

Post, A. S., 1969, Distribution of surging glaciers in western North America: Jour. Glaciology, v. 8, pp. 229-340.

Post, A. S., and Mayo, L. R., 1971, Glacier-dammed lakes and outburst floods in Alaska: U. S. Geol. Survey Atlas, HA-455, 10 pp., 3 pl.

Prest, V. K., Grant, D. R., and Rampton, V. N., compilers, 1968, Glacial map of Canada: Canada Geol. Survey Map 1253A, scale 1:5,000,000.

Rampton, V. N., 1971, Ground ice conditions - Yukon coastal plain and adjacent areas: Grol. Survey Canada Paper 71-1, Part B, pp. 128-130.

-----, 1972, Surficial deposits - Alaska Highway, Whitehorse to Alaska-Yukon boundary: Geol. Survey Canada Paper 72-1, Part B, pp. 119-122.

Richards, J. H., and Fung, K. I., 1969, Atlas of Saskatchewan: Saskatoon Univ., Saskatchewan, 236 pp.

Roddick, J. A., and Green, L. H., 1961, Geology, Tay River, Yukon Territory: Canada Geol. Survey Map 13-1961, preliminary series.

Roed, M. A., 1970, Surficial geology, Edson: Research Council of Alberta Map 33.

Rowe, J. S., 1972, Forest regions of Canada: Can. For. Serv. Publ. 1300, Dept. Environ., Ottawa, 172 pp.

Smith, M. W., and Hwang, C. T., 1973, Thermal disturbance due to channel shifting, Mackenzie Delta, N.W.T., Canada, pp. 51-60 in Permafrost - North American Contribution, 2nd Internat. Conf., Yakutsk, 1973: Washington D.C., Nat. Acad. Sci., 783 pp.

St-Onge, D. A., 1967, Surficial geology, Iosegun Lake (east half) west of fifth meridian, Alberta: Canada Geol. Survey Map 15-1966, preliminary series.

Stevens, A. E., and Milne, W. G., 1973, Seismic risk in the northern Yukon and adjacent areas: Task Force on Northern Oil Development, Rept. No. 73-7, Dept. Energy, Mines and Resources, Ottawa, Canada, 27 pp.

Stevens, A. E., Milne, W. G., Wetmiller, R. J., and Leblanc, G., 1973, Canadian earthquakes-1967: Seismol. Series Earth Phys. Br., No. 69, Ottawa, Canada, 65 pp.

Stichling, W., 1974, Sediment loads in Canadian rivers: Inland Waters Directorate, Water Resources Branch Tech. Bull. 74, 27 pp.

Stott, D. F., 1961, Dawson Creek map-area, British Columbia: Canada Geol. Survey Paper 61-10, 32 pp.

Taylor, G. C., 1963, Geology, MacDonald Creek, British Columbia: Canada Geol. Survey Map 28-1963, preliminary series.

Taylor, G. C., and Stott, D. F., 1968, Fort Nelson, British Columbia: Canada Geol. Survey Paper 68-13, 23 pp.

Tempelman-Kluit, D. J., 1974, Reconnaissance geology of Aishihik Lake, Snag, and part of Stewart River map-areas, west-central Yukon: Canada Geol. Survey Paper 73-41, 97 pp.

Thomas, J. F. J., 1964, Surface water quality in major drainage basins and northern areas of Canada: Jour. Am. Water Works Assoc., v. 56, no. 9, pp. 1173-1193: Reprint Series No. 10, Inland Waters Branch, Dept. of Energy, Mines and Resources.

U. S. Geol. Survey, 1967, Water Resources data for Alaska, Pt. 1 - Surface Water Records: U. S. Dept. of the Interior, 145 pp.

_____1968, Water Resources Data for Alaska, Pt. 2 - Water Quality Records: U. S. Department of the Interior, 99 pp.

Van Everdingen, R. O., 1974, Ground water in permafrost regions of Canada: in Permafrost Hydrology-Proceedings of workshop seminar, 1974: Ottawa, The Secretariat, Canadian National Comm., International Hydrologic Decade, Dept. of the Environment Canada, 1974, pp. 83-93.

Vernon, Peter, and Hughes, O. L., 1966, Surficial geology, Dawson, Larsen Creek, and Nash Creek map-areas, Yukon Territory: Canada Geol. Survey Bull. 136, 25 pp.

Water Survey of Canada, 1968a, Sediment data for Canadian rivers, 1968: Inland Waters Directorate, Dept. of the Environment, 255 pp.

_____1968b, Sediment data for selected Canadian rivers, 1965: Inland Waters Branch, Dept. of Energy, Mines and Resources, 103 pp.

_____1969a, Sediment data for Canadian rivers, 1966: Inland Waters Branch, Dept. of Energy, Mines and Resources, 157 pp.

_____1969b, Sediment data for Canadian rivers, 1969: Inland Waters Directorate, Dept. of the Environment, 261 pp.

_____1970a, Sediment data for Canadian rivers, 1967: Inland Waters Branch, Dept. of Energy, Mines and Resources.

_____1970b, Water temperatures of selected streams in Alberta, Saskatchewan and the Northwest Territories: Dept. of Energy, Mines, and Resources, Inland Waters Branch, Calgary Dist.

_____1972, Surface water data, Yukon Territory and Northwest Territories, 1971: Inland Waters Branch, Dept. of the Environment, 50 pp.

_____1973, Surface water data, Yukon and Northwest Territories, 1972: Inland Waters Directorate, Dept. of the Environment Canada, 54 pp.

_____1974, Surface water data, Reference index, Canada, 1973: Inland Waters Directorate, Dept. of the Environment Canada, 262 pp.

Weir, T.R. 1960, Economic Atlas of Manitoba, Dept. of Industry and Commerce, Province of Manitoba, 81 p.

Wheeler, J. O., 1961, Whitehorse map-area, Yukon Territory: Canada Geol. Survey Mem. 312, 156 pp.

Wheeler, J. O., Green, L. H., and Roddick, J. A., 1960a, Geology, Finlayson Lake, Yukon Territory: Canada Geol. Survey Map 8-1960, Preliminary series.

Wheeler, J. O., Green, L. H., and Roddick, J. A., 1960b, Geology, Quiet Lake, Yukon Territory: Canada Geol. Survey Map 7-1960, Preliminary series.

BLM LIBR
RS 150A BL
DENVER FEDERAL
P.O. BOX 2504
DENVER, CO 802

☆ U.S. GOVERNMENT PRINTING OFFICE : 1976 O—213—135

BLM LIBRARY
RS 150A BLDG. 50
DENVER FEDERAL CENTER
P.O. BOX 25047
DENVER, CO 80225

PROPERTY OF
Bureau of Land Management
DSC LIBRARY

TD 195 .P5 L362 1976h

Alaska natural gas
trans. sys. ... Canada

BLM LIBRARY
RS 150A BLDG. 50
DENVER FEDERAL CENTER
P.O. BOX 25047
DENVER, CO 80225